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Massive galaxy clusters like Abell 2218 have provided scientists with evidence for the existence of dark matter.

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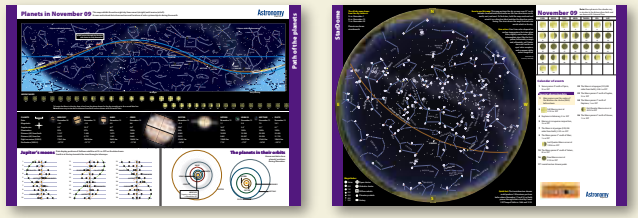

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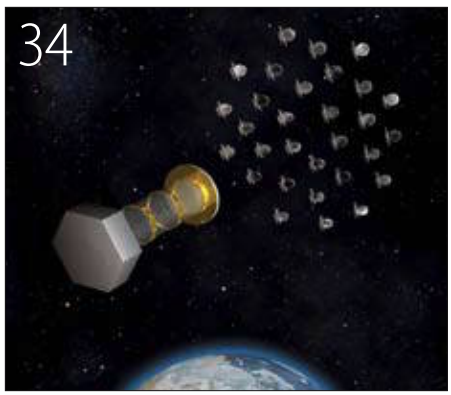

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Check out the blogs on Astronomy.com

by David J. Eicher

If you don't read them already, do yourself a favor and go to www.Astronomy.com/blogs. Every week the editors of *Astronomy* produce a number of posts relating to astronomical news events, meetings, travel, images, book reviews, cool findings, or just plain weird stuff we want to share with you. Sometimes our columnists and contributors also pitch in and produce a post.

Let me present a sample of our blogs so you have a sense of what they are. In a recent post, Copy Editor Karri Ferron described the process of imaging volcanic sunsets. She referred to a column in the May 2009 issue by Stephen James O'Meara in which he wrote about the August 7, 2008, eruption of Kasatochi, a small island volcano in southwestern Alaska. The event had a dazzling side effect — colorful sunsets. Another volcano, Sarychev, erupted in Russia beginning June 12.

"Today, people all across the United States are starting to notice these brilliant lavender sunsets," wrote Ferron. "Sarychev's emissions have created fine aerosols of ash and sulfuric acid in the stratosphere that have spread throughout the Northern Hemisphere. The way these aerosols catch the light causes brilliantly colorful sunsets and crepuscular rays, the rosy fingers of light that radiate up from the sunset point on the horizon."

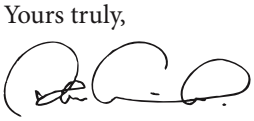
In another post, Senior Editor Michael E. Bakich wrote about the team of British astronomers who created the largest ground-based composite image of the Moon. "Damian Peach is a friend of mine and a British planetary astrophotographer who has been sending me high-quality images for as long as I've been at the magazine," wrote Bakich. "He just sent me word of the completion of an incredible project.

"In April, a team of astroimagers gathered at the home of British astronomer and popularizer Sir Patrick Moore. There, they decided to create the largest ground-based mosaic image of the Moon and enter the Guinness World Records."

Bakich continued: "The group imaged the 9-day-old Moon through video cameras attached to long-focal-length telescopes. The team captured 1.2 million frames of video totaling 1.1 terabytes of data. Through processing, that number became almost 1,000 images."

That's just a sample of the posts you'll find in our blogs. If you're not regularly checking them, I encourage you to do so and to send us your comments to let us know how we're doing.

Yours truly,



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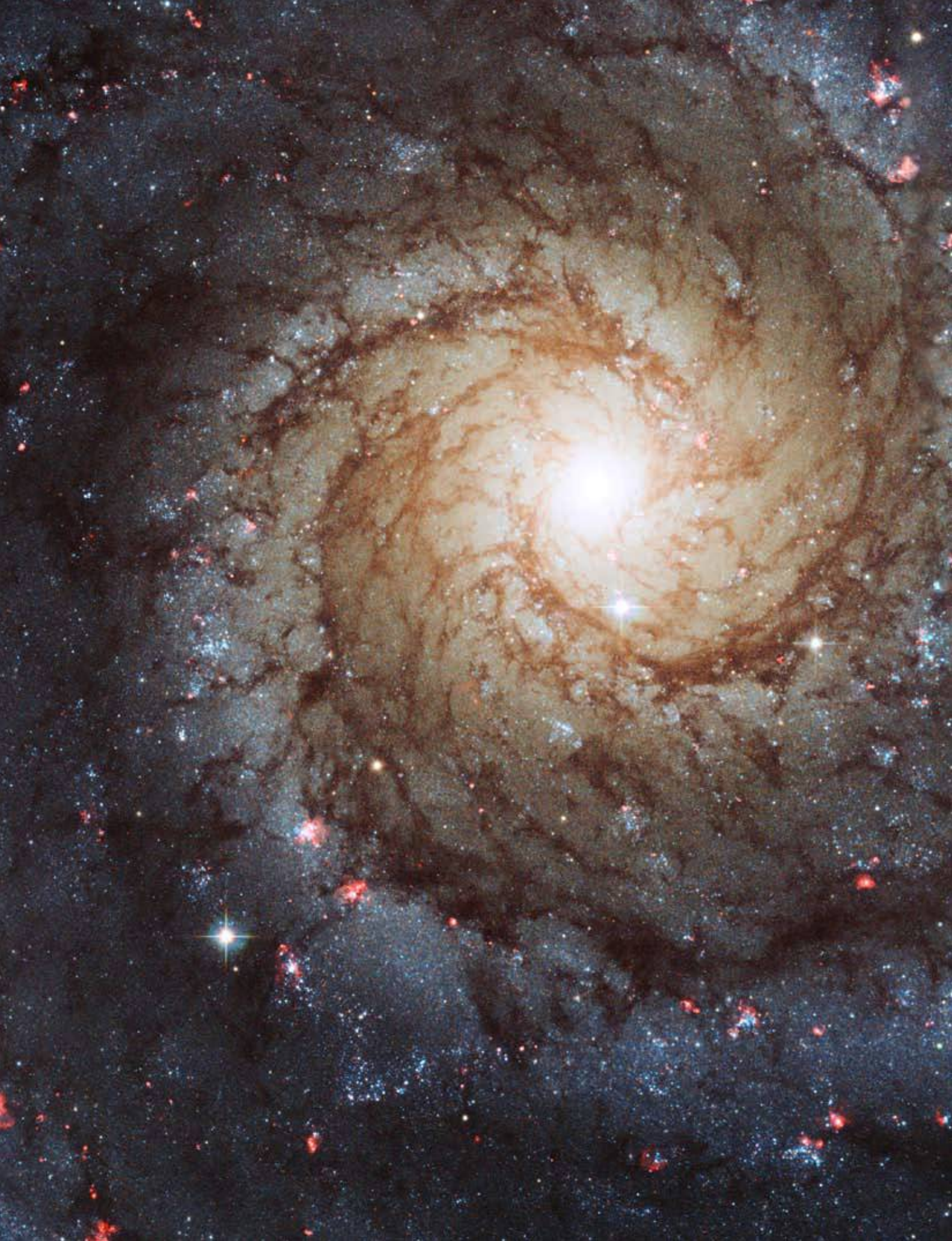


Spiral designs

If you set out to construct a perfect galaxy, you'd be hard-pressed to design anything better than M74 in the constellation Pisces the Fish. A so-called grand design spiral, this galaxy features prominent and symmetric spiral arms displayed nearly face-on to our line of sight. Bright blue star clusters, pink clouds of star formation, and opaque dust lanes highlight the arms. These wind out from a nucleus of much older, redder stars. M74 lies roughly 32 million light-years from Earth. This Hubble Space Telescope image spans a bit more than 30,000 light-years, or about one-third of the galaxy's total extent.

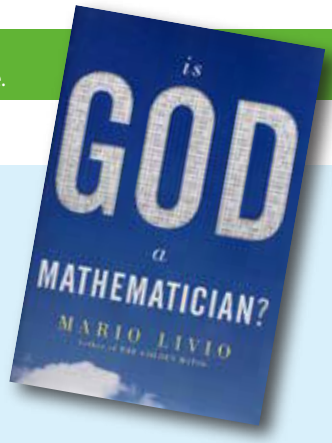
NASA/ESA/Hubble Heritage Team (STScI/AURA)

OUR TURN

Mario **Livio**

Senior astrophysicist at the Hubble Space Telescope Science Institute in Baltimore and author of *Is God a Mathematician?* (Simon & Schuster, 2009)

Will Kirk/Home Photographic Services



What inspired you to start writing books for the public?

Most people are actually very interested in science, more so than some would think. It's true that they're not interested in all areas of science, but most are very interested in things related to origins — how the universe began, how the solar system formed, how galaxies start, how life originated on Earth, and so on.

Over the years, I have given probably thousands of public talks. And at some point, I said, "I probably can reach people if I actually put some of this down in the form of a popular book." This is how I started writing these books, and once you get hooked, I guess it's hard to stop. So I've published four books really intended for people interested in some aspect of science.

What is one of the greatest challenges facing astronomy today?

I have to say dark energy. Its nature is arguably the biggest question physics faces today. I've given this a lot of thought, much more so than the actual number of papers I've written on the topic. Partly it's because I do not see a very easy breakthrough.

I have written at least one paper on the possibility that we must think in terms of anthropic reasoning — the notion that our universe is one of many, and some physical phenomena that are otherwise a mystery may be explained by our universe having to be such as to allow for complexity and intelligent life to emerge within it. This is not the way I would like the dark energy problem to be solved.

I hope dark energy will find explanation in the first principles of physics. But I might have to adjust my hopes. We may have to fall back on anthropic reasoning or a combination of the two.

What I do see, though, is that the answer is not going to come fully from observations. This is definitely one case where better observations will have to be accompanied by a real breakthrough in theoretical understanding, or we will not understand this phenomenon.

Astro**influences**

How did you get interested in super star clusters?

I was fortunate to be in the right place at the right time with the right advisor.

In my first year of graduate school in astrophysics, I didn't know much about the cutting-edge research being done with super star clusters or the main outstanding problems in the field. Instead, I was (and still am) fascinated by everything in the universe.

But then my soon-to-be advisor asked me to visit the Space Telescope Science Institute, which runs the Hubble Space Telescope, to work on some data he'd gotten. This wasn't long after the first Hubble repair mission, so I knew the telescope's data would be spectacular. In fact, shortly after the optics were fixed, super star clusters really came into their own as an area of study — before this, the available ground- and space-based images were too fuzzy to see these compact objects.

Still, I knew nothing about the science involved or the data. I was overwhelmed. So I kept a long list of questions about super star clusters to which I was pretty sure answers already existed or were possible with a little physics, and I worked my way through the list. Bit by bit, I started piecing together a better understanding of the field.

Then one day while explaining my research to some fellow graduate students, I began to get a clear sense that these clusters really are incredibly interesting. Super star clusters challenge our current understanding of star formation and provide insight into the conditions in the earlier universe. Once my own research started to add to our understanding of these objects, I was hooked.

Tom Cogill

Kelsey **Johnson**

Assistant professor of astronomy at the University of Virginia

A DAY IN THE LIFE OF ...

Courtesy Chuck Steidel

Chuck **Steidel**

Astronomy professor at the California Institute of Technology in Pasadena

A night observing at the W. M. Keck Observatory, Mauna Kea, Hawaii

1 P.M. Gather in the Remote Operations Room at Keck headquarters in Waimea, at an altitude of 3,000 feet. Observatory staff at the summit (14,000 feet) "release" the instrument we'll use for our project (deep spectroscopy of galaxies at a distance of 10–12 billion light-years), and we get calibrations of every conceivable kind and double check that everything is ready to go.

6 P.M. Observing Assistant at the summit (whom we communicate with via video-conferencing) opens the dome for more calibrations using the twilight sky. Poised to line up on our first field well before dark. We have waited more than 6 months for 2 nights of observing to complete our project, and, as a rough rule of thumb, observing time is worth a bit more than $1 per second.

10 P.M. After the first set of observations, start crunching the data that two CCD cameras have recorded digitally. Without significant processing, really have no idea if we are getting something useful — the "quick-look" data reduction shows a very good signal lurking in the sea of sky background — but we move on. One of us watches four video screens that monitor the spectrometer and allow us to reconfigure it as needed. The other tries to keep up with data crunching to get feedback on our progress.

6 A.M. Get another set of calibrations and let the Observing Assistant know that she can "put the telescope away."

8 A.M. Roll into bed in the Visiting Science Quarters only a few steps from the Remote Operations Room for 4 hours of sleep before another 20-hour session.

GETTING TO KNOW

Courtesy Kim Weaver

Kim **Weaver**

Astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Maryland, and adjunct professor at Johns Hopkins University in Baltimore

"Coolest" thing about X-ray astronomy: The coolest thing about X-ray astronomy is the chance to learn about some of the hottest and most extreme physical environments in the universe. X-ray telescopes, or our "X-ray eyes in the sky," are some of the tools we can use to learn about extreme gravity, big explosions, and fast-moving particles. X-rays give us information that our eyes can't see. If you want to learn what happens near a black hole, the most direct way to probe this using traditional astronomy is with X-rays.

Major goals for the next 5 years: I'm evaluating my goals. When I was getting my Ph.D., the only thing I could see was being a full-time research astronomer. I still like it, but as I have expanded my world to take on new challenges and to reach out to the public through the media, I found a new part of myself emerging. I like doing multiple things. Sometimes it's managing press efforts for NASA. Sometimes it's meeting people. Sometimes it's writing popular articles. I have a strong artistic and musical side. I compose music and have performed both as a musician and an actor. Maybe in 5 years I'll be writing a musical about being a scientist.

Greatest challenges facing astronomy today: The greatest challenge is the conflict between expectation and funding. Modern astronomy can require large satellites and enormous ground-based telescopes that can cost lots of money. There is only so much money to spare within our economy, so astronomers have to make some tough choices. The excitement of astronomy can conflict with the reality of fiscal limitations. Astronomers often must wait until the right telescopes can be built and commissioned for their particular field of work. Astronomy is not an "instant-gratification" science. If you're in it, you're in it for the long term.

Astro**ideas**

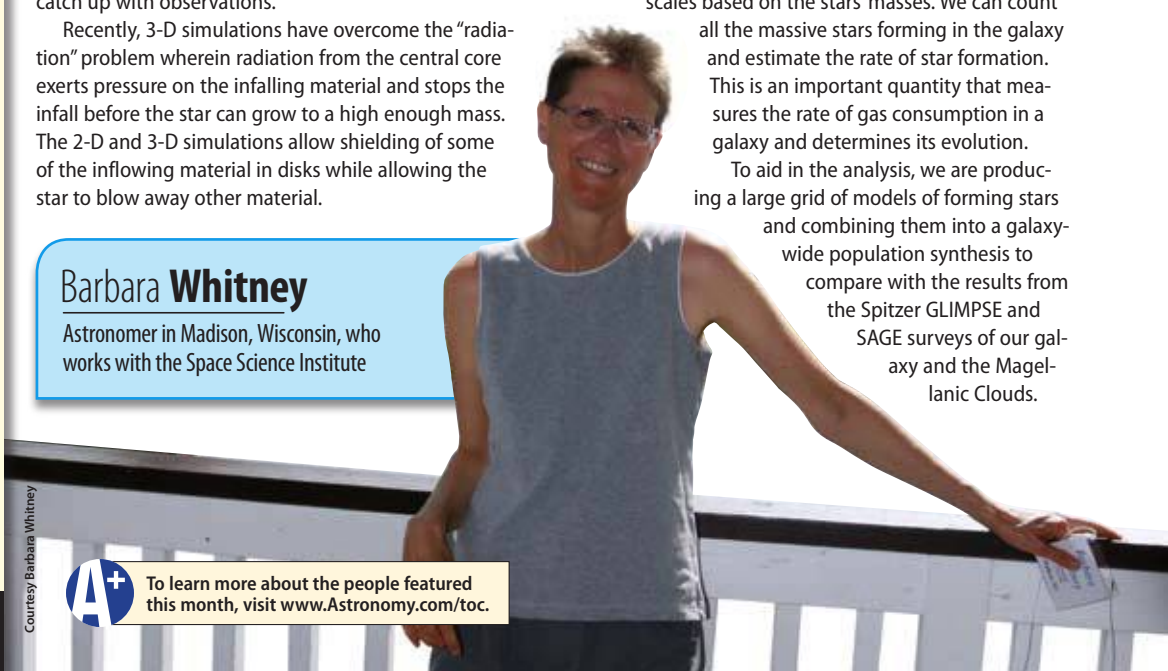
What are the current big ideas in infrared astronomy?

One of the big questions that infrared astronomy can help answer is how massive stars form. Until very recently, theory couldn't do it. We know there are stars 50–100 times the mass of the Sun, but theoretical models couldn't build them. This led to speculation that massive stars form from mergers of lower-mass stars. However, theory is finally starting to catch up with observations.

Recently, 3-D simulations have overcome the "radiation" problem wherein radiation from the central core exerts pressure on the infalling material and stops the infall before the star can grow to a high enough mass. The 2-D and 3-D simulations allow shielding of some of the inflowing material in disks while allowing the star to blow away other material.

Observationally, the Spitzer Space Telescope is revealing thousands of massive young stellar objects throughout our galaxy as well as the nearby Large and Small Magellanic Clouds. These distant objects are deeply embedded in dark clouds and too faint or blurry for previous observatories to detect. Now we can do statistical studies to determine numbers and evolutionary time scales based on the stars' masses. We can count all the massive stars forming in the galaxy and estimate the rate of star formation. This is an important quantity that measures the rate of gas consumption in a galaxy and determines its evolution.

To aid in the analysis, we are producing a large grid of models of forming stars and combining them into a galaxy-wide population synthesis to compare with the results from the Spitzer GLIMPSE and SAGE surveys of our galaxy and the Magellanic Clouds.



Courtesy Barbara Whitney

Barbara **Whitney**

Astronomer in Madison, Wisconsin, who works with the Space Science Institute

To learn more about the people featured this month, visit www.Astronomy.com/toc.

The Pluto debate

Congratulations on the department "Astro Confidential," featuring the human element of astronomy. But regarding the noted Neil deGrasse Tyson of the Hayden Planetarium in New York (profiled in the July *Astronomy*), one has to wonder about his endorsement of the flawed International Astronomical Union's downgrade of Pluto to "dwarf planet" status. As noted later in the same issue (page 20), the debate on this decision "rages on throughout the astronomical community and the general public."

Meanwhile, NASA's New Horizons space probe moves toward a 2015 arrival at Pluto. That could result in many more surprising findings about this fascinating world Clyde Tombaugh discovered in 1930. — **Earl Finkler,** Medford, Wisconsin

While at the June meeting of the American Astronomical Society, I attended a forum regarding the definition of a planet — and how Pluto fits in. There were seven prominent scientists on the panel (including Tyson). From listening to the panelists, it sounds like it's premature to conclude whether the IAU's definition of a planet should remain. However, scientists need more data to arrive at an accurate definition. That information should come soon from observations and spacecraft like New Horizons. — **Liz Kruesi,** Associate Editor

The New Horizons craft will study Pluto and its moon Charon in 2015 and then continue on to encounter a few Kuiper Belt objects.

Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute

Reinstate the dream

July 20 marked the 40th anniversary of the Apollo 11 lunar landing. In 1969, millions of television viewers watched astronaut Neil Armstrong take his first step on lunar soil and proudly proclaim, "That's one small step for [a] man, one giant leap for mankind." For one shining moment in history, Earth stood still, and humanity took one giant leap into the unknown!

What happened to the American dream of exploring space? I look at the Moon and wonder when we'll go back. I look at Mars and wonder if we'll ever get there. Human exploration of the Moon, Mars, and beyond would restore national pride and bring purpose to our space program. Space exploration would be an investment in our future and a benefit to humanity.

I remember the Apollo 11 lunar landing as a positive achievement for the United States. I hope Americans press on to make the unknown elements of space known to our world. With a new vision and dedicated leadership, President Obama and NASA Administrator Charles Bolden can put NASA back on course. Let's keep the dream alive and boldly step back on the Moon! — **Rick Schreiner,** San Marino, California

Flush with excitement

For almost the entire 50-year span of my life, I've been an avid amateur astronomer and space enthusiast. With all my enthusiasm for the subject, this personal passion has never crossed the genetic line to my children. Sound familiar?

Well, it didn't take me too long to understand as my kids were growing up that astronomy wasn't their "cup of tea." Thankfully my wife, Leslie, has a rudimentary knowledge of the stars, which she acquired from her father when she was growing up. But even that was not enough to kindle an ongoing interest in astronomy. After a few family late-night observing sessions, which also included a meteor shower one summer night, I came to the full realization that my wife and my kids were only mildly interested at best. At that point I knew I was probably going it alone on this one.

So I went about my business, singularly enjoying my passion. Then one day, like the discovery of a comet or a supernova, my entire astronomy world changed! My wife was in our guest restroom, a place she rarely ventures into. I had recently cleaned out the room's magazine rack with the exception of my most recent editions of *Astronomy* magazine. Yes, this bathroom library was my "*Astronomy* haven" — the one place I most often frequent for a quiet read of *Astronomy*.

As she left the restroom, she exclaimed, "Did you read what Bob Berman wrote about in his latest column?" I stood there in amazement. Was she actually reading *Astronomy* magazine? Sure enough, she was, and the rest is history.

Thanks Bob! You were able to accomplish in one short bathroom read something I couldn't achieve in almost 25 years of marriage! You captured my wife's interest in astronomy to the point that she now reads large portions of the magazine. This, in turn, has led us to some very enlightened conversations. The jury is still out regarding my kids and astronomy, but for at least the foreseeable future, my wife has joined the ranks. "Strange Universe" you say, Bob? You can say that again! — **Steve Cardiasmenos,** San Carlos, California

Corrections

In the photograph on page 8 (August), the astronaut climbing out of the lunar module is Buzz Aldrin. However, Neil Armstrong was the first human to stand on the Moon.

In the August issue, the last sentence of the caption on the bottom-right of page 52 is incorrect. In 1967, Surveyor-III was the first spacecraft to photograph an eclipse from the lunar surface.

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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Strange Universe

by Bob Berman

Can you imagine?

In Galileo's time and in ours, some science concepts are inconceivable.

Astronomy offers a wonderful blend of observing and imagining. We gaze at Saturn's rings. They're real, not abstract at all. Later we hear that its moon Titan has methane pools. Few of us have ever seen liquid methane, but supposedly it looks just like water, so we simply visualize a landscape of lakes and ice boulders. Titan is easy to imagine.

Then we read about string theory's 11 dimensions. What do we picture now? Nothing. Perhaps we feel we're not smart enough to visualize them. In reality, our school teachers neglected to reveal a vital fact about science: Some things cannot be imagined. Maybe we should know what they are.

Picture this: You're an astronaut on a planet with red polka-dot clouds. The surface is a vast rubber sheet. As you bounce along, you suddenly see a flock of flying bulldogs. The pack leader hovers in front of you like a hummingbird and speaks perfect English: "Welcome. Can you help settle a debate we're having?"

"Um, sure," you say.

The alpha bulldog whispers: "Who was the greatest baseball player of all time?"

You guess, "Ruth?" And that's what they all wanted to hear. The dogs excitedly bark, "Ruth! Ruth!" as they lick your face until you're covered with slobber.

The point isn't that I'll never make a living writing fiction. It's this: There's no such thing as polka-dot clouds, rubber planets, or flying dogs. Yet you had no trouble picturing the whole thing. That's because our minds can easily weave familiar elements into a new context. Titan's surface or flying dogs present no challenge for our imaginations.

But now consider Galileo's observations of Saturn's rings. Even after decades of studies, he never figured out what he was seeing. He thought the rings were like teacup handles. It took nearly half a century before Christiaan Huygens finally got it right. That's because Saturn's shape lay outside human experience. On Earth, there is no example of a ball surrounded by unattached rings. Spiral galaxies resemble nautilus shells, nebulae look like clouds, star clusters like spilt sugar. Alone among nature's marvels, Saturn had no analog.

A bear wanders past my window once or twice each year. At first glance, I always think: huge black dog. Then the truth hits. One's initial impulse is to perceive the familiar.

We are all prisoners of our backgrounds and experiences. Conceptual struggles arise when, as with Galileo, there are no associations, no past experience. You cannot explain the color blue to a person born blind.

Conceptual struggles arise when there are no associations, no past experience.

Equally inconceivable are any extra dimensions beyond the width, depth, and height of everyday 3-D objects. If additional "string" dimensions exist, they cannot be pictured — by anyone. We've all been "born blind" to them.

Then there's quantum theory, which has a virtual patent on the inconceivable. Quantum theory reveals objects' behaviors as neither logical nor illogical, but "non-logical." Say an electron has two possible routes from its source to a detector. The equipment shows it arrived, but it didn't follow path A or path B. It also didn't take neither path — if they're both blocked, the electron goes nowhere. Nor did it somehow occupy both. Because these are the only choices we can entertain, we're stumped. Not A, not B, not neither, and not both. It did *something else*. Physicists just shrug and say this particle was in a state of "superposition." But they can't imagine what that actually means.

Or consider the common question, "What is the universe expanding into?" People usually think of an inflating balloon. However, the correct way to visualize an expanding universe is to picture all galaxy clusters rushing directly away from you, no matter where you're located. This simply means that the space between galaxy clusters is growing larger everywhere.

If you instead picture the universe as if you were outside of it, you're making a mistake. Nothing exists beyond the universe, by definition. Because you cannot view it from the outside, that particular visual dilemma goes away.

Does this still leave unanswered questions? Sure. But any study of the universe as a whole *must* arrive at barriers where no further visualizations are available. That's just how it's set up. Infinity, the Big Bang zero moment, singularities, curved space, superposition: Many science ideas can be stated but not imagined. This is especially true of cosmology.

So don't ever feel insecure. Experts cannot do much better than you can. Cosmologists use more math and carry cause-and-effect relationships a few extra steps. But their endpoints are just as inconceivable as your own.

Once you accept this, you no longer feel stupid. Or else you feel more stupid.

Not sure which.

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Secret Sky

by Stephen James O'Meara

Extreme observing: naked-eye galaxies

Find a dark sky and test the limit of your eyes with these deep-sky targets.

When we look up at the night sky, far away from city lights, how far can we see without optical aid? It's easy (and fun) to imagine that the distance is infinite, but it's not. Our eyes have limits.

Whereas patients during daytime eye exams try to resolve letters of ever-diminishing size on a chart 20 feet away, amateur astronomers test their visual prowess by trying to detect ever-fainter objects tens, hundreds, or even millions of light-years distant. Under dark, transparent skies, skilled naked-eye observers have accomplished some amazing visual feats, and the distances they reach keep getting deeper.

It's our nature to explore, to push the limits of understanding. We always want to know what lies beyond the veil separating the known from the unknown. This yearning has been effectively depicted in a famous wood engraving possibly created by Camille Flammarion, who first published it in his 1888 book, *The Atmosphere: Popular Meteorology*. It shows a medieval pilgrim poking his head through the scrim of the sky to see what wonders exist beyond.

In the famous wood engraving, a man dressed as a medieval pilgrim looks through the sky in search of understanding the universe. Oberon Design

The Pinwheel Galaxy (M33) is one of the Milky Way's nearest neighbors, at some 3 million light-years away. This galaxy's luminous central core should be visible to unaided eyes from an extremely dark, clear sky location. Daniel B. Phillips

In a sense, I'm asking you now to do just that: to look beyond the star-studded veil of our Milky Way and search for three naked-eye galaxies. All are well-placed high above the southern horizon shortly after sunset during autumn. Even if you can't see them with your eyes alone, the galaxies are certainly fun to track down with binoculars and telescopes.

In the end, you might be amazed at just how far you can see!

A simple wonder

By far the brightest naked-eye galaxy beyond our Milky Way system is the Andromeda Galaxy (M31). This spiral wonder appears to the naked eye as a faint elliptical glow spanning 3° by 1° of sky. If you could collect all of its light and squish it into a point, the galaxy would appear about as obvious as a 3rd-magnitude star. But we can't, and it doesn't. Instead, you should look for an ill-defined cigar-shaped haze 6 apparent Moon-widths in length and 2 in width.

Finding M31 is simple. First locate 2nd-magnitude Alpheratz (Alpha [α] Andromedae), which marks the northeastern corner of the Great Square of Pegasus. Now look about 15° northeast for the lovely Girdle of Andromeda — a slender 7°-long arc of three obvious stars oriented southeast to northwest: 2nd-magnitude Beta (β) Andromedae, 4th-magnitude Mu (μ) Andromedae, and 4.5-magnitude Nu (ν) Andromedae, respectively. M31 lies about 1½° west-northwest of Nu.

Sharp observers have detected the galaxy's bright central region from some cities, although it is difficult, and knowing exactly where to look is important. Under a dark, moonless sky, M31 has an attractive glow and looks to the

unaided eye like M88 in Coma Berenices as seen through a small telescope at 20x. Under such conditions, my wife, Donna, could see the galaxy's northwestern edge sharply cut off — the consequence of a dust lane running along that part of M31's disk.

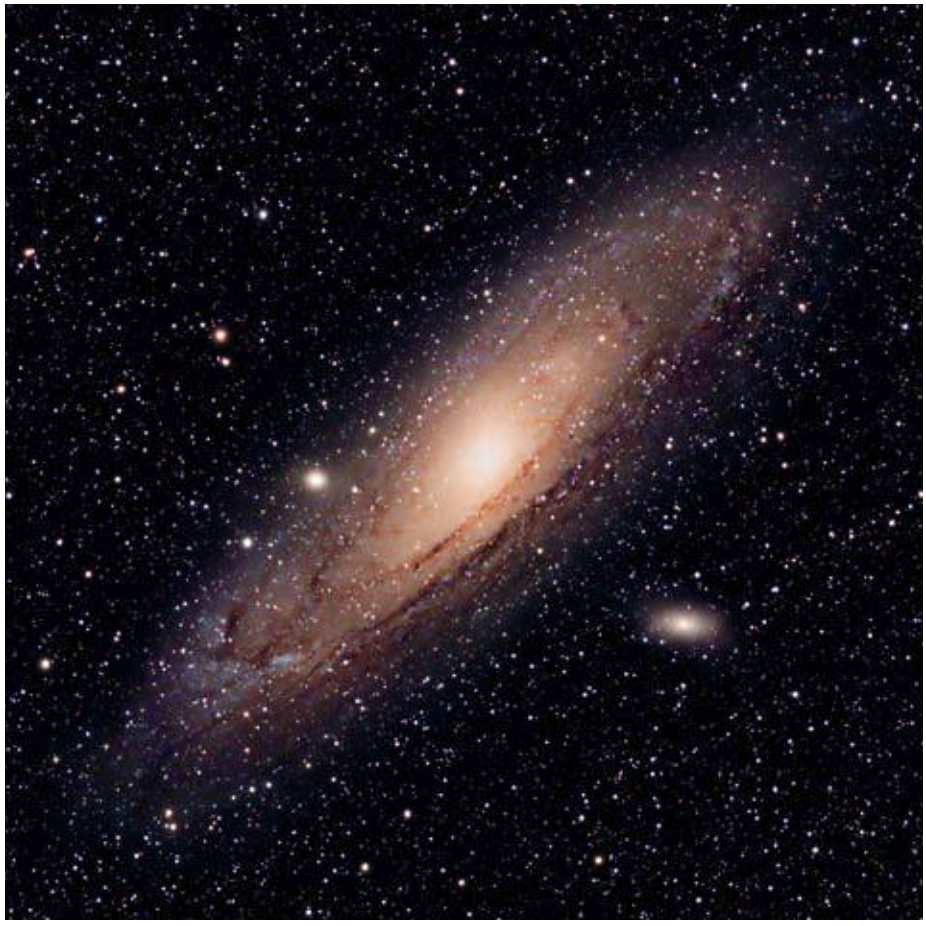
At a distance of 2.9 million light-years, M31 is, without exception, the farthest object one can see easily without optical aid.

A sky test

Return your sights to Beta Andromedae. Now look about 10° southeast for 3rd-magnitude Alpha Triangulum. M33, the great Pinwheel Galaxy in Triangulum, lies just about 4° west-northwest of Alpha. At magnitude 5.7, M33 is a little more than 2 magnitudes dimmer than M31 and 2½ times smaller in apparent length. If you think a 6th-magnitude star is a challenge to see with your unaided eyes, imagine trying to detect that same light spread across an area roughly equivalent to 2 Moon-widths. Although M33's extent covers that much area of sky, the galaxy fortunately has a bright and highly condensed nuclear region, which is what you should try to spot.

Not surprisingly, M33 has had a yin-yang history of naked-eye attempts: Many people have failed to see it; many others have snagged it without difficulty. Sky conditions may be the main reason for this situation. Even the slightest light pollution or atmospheric impurity will dampen your chances of spotting it. If you fail to sight it one night, try again on another evening.

The Silver Coin Galaxy (also known as the Sculptor Galaxy [NGC 253]) lies about 10 million light-years away but is visible to unaided eyes from certain locations. It'll take patience to see this galaxy. R. Jay GaBany



While the Andromeda Galaxy (M31) is spectacular in photographs, it's also a thrill to observe with unaided eyes. Under a dark sky, you should be able to spot it as a faint glowing cloud. Warren A. Keller

In his 1999 book *Deep-Sky Wonders*, the late Walter Scott Houston noted that in 1954, while observing meteors 8 miles east of Manhattan, Kansas, he accidentally "stumbled on" M33. Houston wrote that it "was so obvious that at first I took it for a bit of cloud."

Becky Ramotowski of Tijeras, New Mexico, says M33 is an "easy" target under very dark skies at 7,000 feet (2,100 meters). Indeed, Brent Archinal, who lives near Flagstaff, Arizona, says M33 is "fairly commonly seen" by skilled naked-eye observers, like Ramotowski.

If you can see M33, you will have peered 3 million light-years into space, beating M31 by 100,000 light-years.

The deep

Our next galaxy truly belongs to the naked-eye deep. NGC 253, the Silver Coin Galaxy in Sculptor, requires a good southerly locale, very dark skies, and (preferably) altitude. With a declination of –25°17′, it lies at roughly the same distance above the southern horizon as Antares in Scorpius, which puts mid-northern observers at a disadvantage.

You'll find it 7½° south-southeast of 2nd-magnitude Beta Ceti, or 4¾° northwest of 4th-magnitude Alpha Sculptoris. Use binoculars to spot it first, then lower the binoculars, settle into a comfortable position, relax, breathe deep, and prepare to dedicate several minutes of intense searching with averted vision.

NGC 253 is, by my estimate, magnitude 7.1, making it a full magnitude fainter than the faintest stars seen by human eyes. Its disk is only 26′ in length, so its light is concentrated in an area of sky nearly 3 times smaller than that of M33. Indeed, I find NGC 253 easier to see (under dark Hawaiian skies at altitude) than M33.

If you do spy the Silver Coin, you've penetrated some 10 million light-years into space. But even this is not a record. Next spring, I'll help you push your eyes to an even more extreme limit. As always, send your observations to me at someara@interpac.net.

NEOs on the web NASA has launched a new web site, www.jpl.nasa.gov/asteroidwatch, to provide up-to-date information on all near-Earth asteroids and comets.

For the latest news on space discoveries, spacecraft missions, and sky events, visit **Astronomy.com/news**

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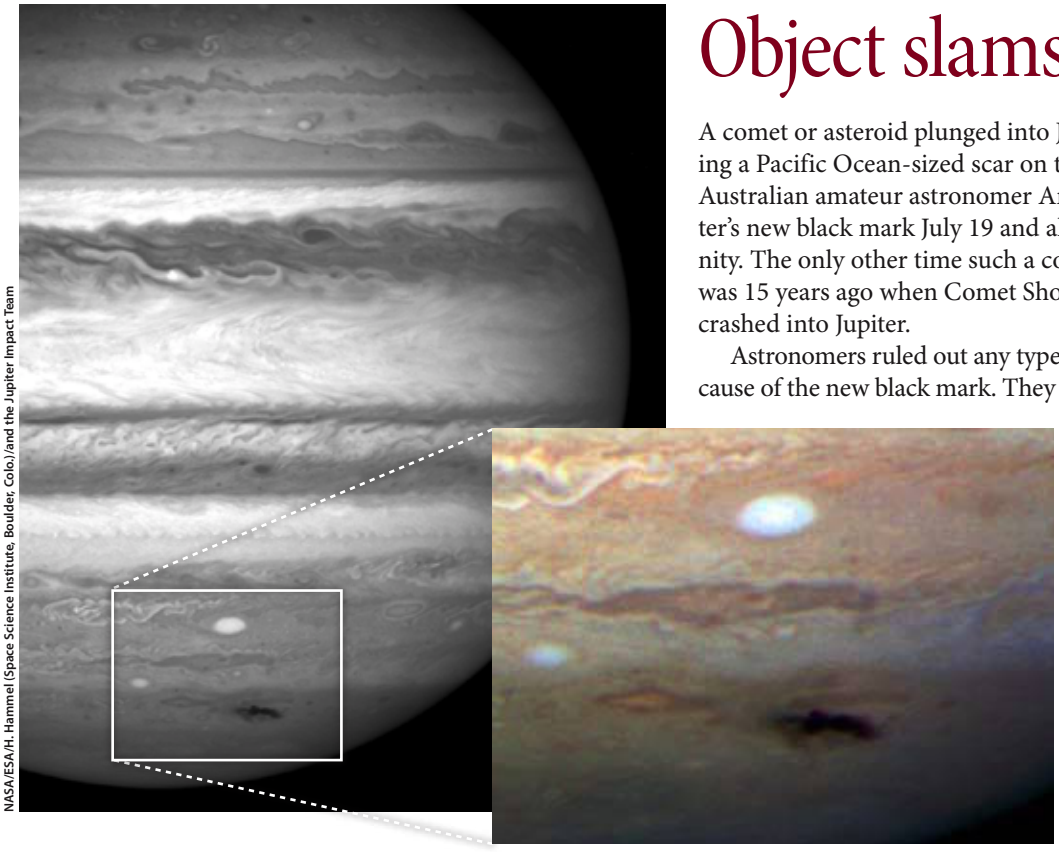


NASA/ESA/H. Hammel (Space Science Institute, Boulder, Colo.)/and the Jupiter Impact Team

Object slams into Jupiter

A comet or asteroid plunged into Jupiter's atmosphere in July, leaving a Pacific Ocean-sized scar on the gas giant's south polar region. Australian amateur astronomer Anthony Wesley discovered Jupiter's new black mark July 19 and alerted the astronomy community. The only other time such a collision on Jupiter has been seen was 15 years ago when Comet Shoemaker-Levy 9 fragmented and crashed into Jupiter.

Astronomers ruled out any type of weather phenomenon as the cause of the new black mark. They think whatever collided with Jupiter was several hundred yards across, but they're not sure what actually crashed into the gas giant. The spot's shape, however, should help astronomers determine what the object was. — **LIZ KRUESI**

Black eye. **Something crashed into Jupiter in July, thus creating a black scar on the planet's south polar region. The Hubble Space Telescope took this image 4 days after the scar appeared.**

22 An ocean in Venus' past?

22 LRO takes first Moon images

23 Citizen scientists help discover a new group of galaxies

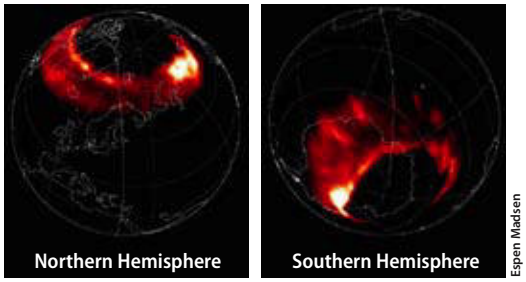
25 Spitzer: Warm is good

26 Comets not to blame for mass extinctions

Aurorae are not mirror images

Earth's northern and southern aurorae are not symmetrical, say researchers Nikolai Østgaard and Karl Magnus Laundal in the July 23 issue of *Nature*. Charged particles from the Sun collide with Earth's magnetic field. Interactions between those particles and Earth's atmosphere cause the aurorae. Scientists had thought the aurorae would be symmetrical because the magnetic field lines connect the two hemispheres.

Two satellites happened to be positioned over the north and south poles at the same time, which allowed simultaneous recording of the May 12, 2001, aurorae. Researchers found that the two looked quite different. There was a persistent intense spot during dusk in the Southern Hemisphere, while the Northern Hemisphere had a transient spot at dawn.



Espen Madsen

Mixed up. **The northern and southern aurorae aren't symmetrical in these May 12, 2001, observations.**

The scientists aren't sure what could cause the asymmetries. However, an aurora-observing experiment with several spacecraft to observe simultaneously would help answer the question. — **L. K.**

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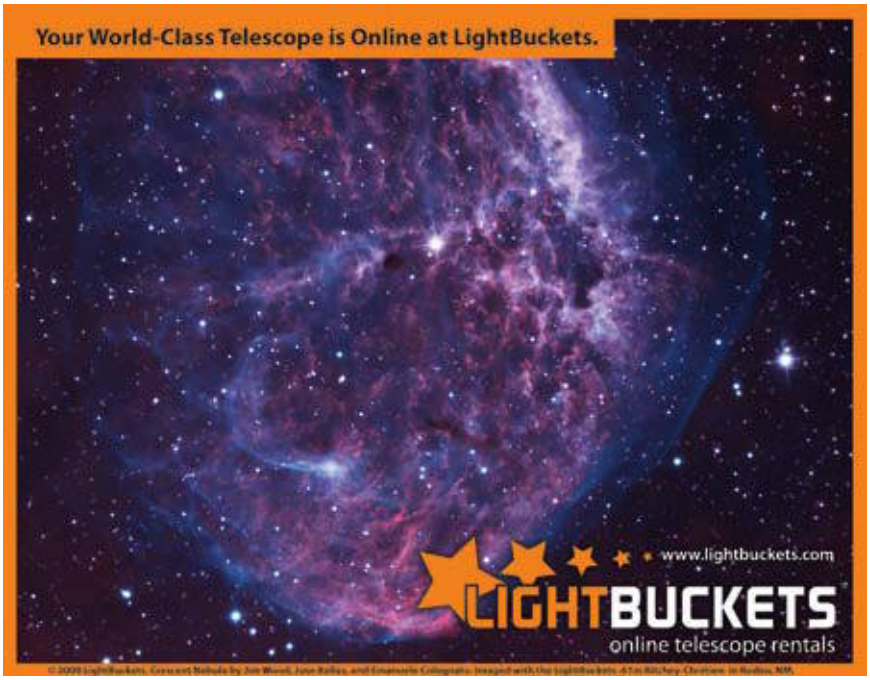

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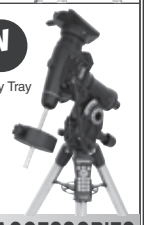

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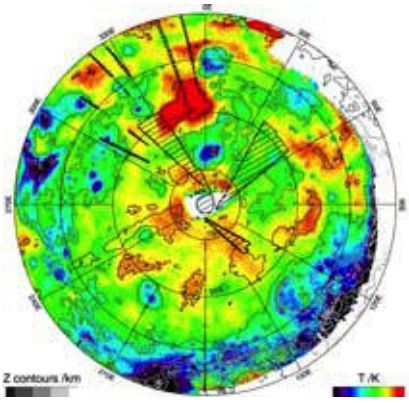


ESA/VIRTIS/INAF-IASF/Paris Observatory-LESIA

Heat probe. In this thermal map of Venus, temperatures range from 792° F (422° C), in blue, to 828° F (442° C), in red. The map suggests the cooler highland regions are ancient continents once surrounded by an ocean.

An ocean in Venus' past?

The first infrared map of Venus' southern hemisphere shows that Earth's neighbor may once have had an ocean of water and a surface wracked by plate tectonics. The map, produced from data returned by the European Space Agency's (ESA) Venus Express spacecraft, reveals temperature differences that hint at the composition of the planet's surface rocks.

Infrared radiation penetrates the thick clouds that completely cover Venus. The mapping team, led by Nils Müller of the University Münster and DLR Berlin in Germany, combined more than 1,000 images recorded over 20 months. The resulting map shows that the surface temperature varies by at most 36° Fahrenheit (20° Celsius). ESA released the map July 14.

Much of Venus consists of basaltic rock. But the new map indicates that rocks on two large plateaus, Phoebe and Alpha Regio, appear older and lighter in color than the majority of the planet. On Earth, such light-colored rocks are usually granite and make up continents.

Granite forms when plate tectonics drives ancient basaltic rocks into a planet. Water combines with the basalt to create granite, which then gets reborn through volcanic eruptions.

"If there is granite on Venus, then there must have been an ocean and plate tectonics in the past," says Müller. He cautions that the only way to confirm these results, however, is to land a spacecraft on the plateaus. — **RICHARD TALCOTT**

LRO takes first Moon images

NASA's Lunar Reconnaissance Orbiter (LRO) has started snapping pictures of the Moon's rugged surface. Mission controllers activated the spacecraft's camera June 30, 7 days after it reached lunar orbit. NASA released the first images from the Lunar Reconnaissance Orbiter Camera (LROC) in early July and has kept them coming in a steady stream ever since.

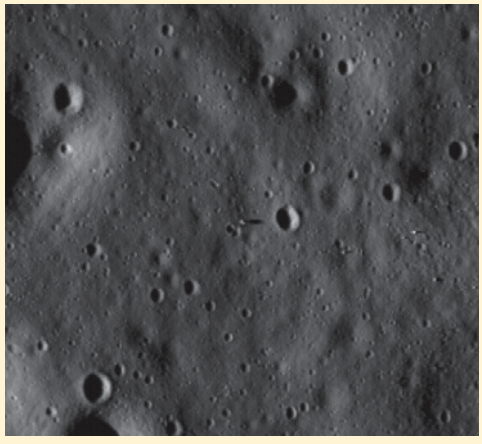
"Our first images were taken along the Moon's terminator — the dividing line between day and night — making us initially unsure of how they would turn out," says LROC Principal Investigator Mark Robinson of Arizona State University. "Because of the deep shadowing, subtle topography is exaggerated."

The initial images revealed an area on the Moon's nearside just a couple of miles east of the crater Hell E, which lies in the lunar highlands south of Mare Nubium. Although the Sun's low elevation in the Moon's sky makes the surface look craggy, it bears more resemblance to the relatively flat regions explored by the Apollo astronauts.

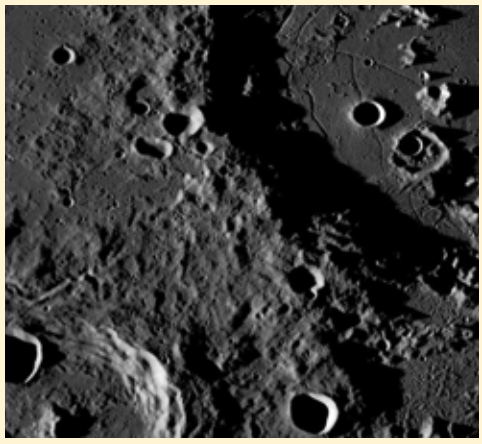
In mid-July, LROC targeted five of the six Apollo landing sites. In each case, the camera captured the lunar module descent stage and its long shadow. The image resolution varied slightly for each site because LRO was in an elliptical orbit, but all were around 4 feet (1.2 meters). So, the Apollo relics filled an area of about 9 pixels. The descent stages cast distinct shadows that filled roughly 20 pixels apiece. Once LRO reaches its final mapping orbit (which should have happened in August), images of these sites should have 2 to 3 times better resolution.

For at least the next year, LRO and its seven science instruments will map the Moon in unprecedented detail, search for lunar resources, and scout out possible landing sites for future human exploration. If the first results are any indication, it should be an exhilarating ride. — **R. T.**

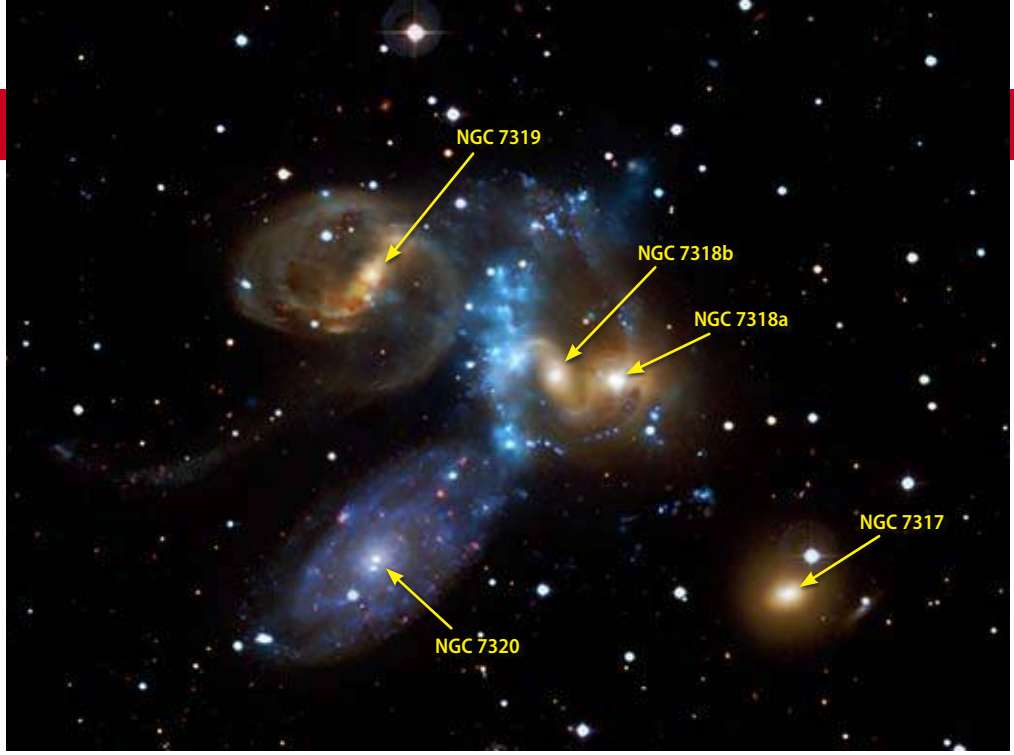
Light and shadow. A low Sun angle throws this terrain south of Mare Nubium into stark relief. Among the first images returned by the Lunar Reconnaissance Orbiter's (LRO) Narrow Angle Camera, this scene spans just 0.87 mile (1.4 km). NASA/GSFC/ASU



Tranquillity Base here. The Apollo 11 lunar module Eagle and its shadow sit at the center of this LRO image. This view measures 534 feet (163m) across. NASA/GSFC/ASU



Cracked crater. Part of the large impact crater Gauss lies at the upper right of this Wide Angle Camera view. The crater, some 110 miles (177 km) across, was once flooded with lava, which later solidified and cracked. NASA/GSFC/ASU



X-ray: NASA/CXC/CfA/E. O'Sullivan; Optical: Canada-France-Hawaii-Telescope/Coelum

Body slam. **NGC 7318b in Stephan's Quintet is moving through the galaxy group. The interaction creates a shock wave that lights up in X-rays (the bright cyan arc through the center).**

Colliding galaxies have shocking good time

The Chandra X-ray Observatory snapped an image of interacting galaxies in Stephan's Quintet, a compact group of galaxies about 280 million light-years away. One of the galaxies (NGC 7318b) is passing through the group's core at almost 2 million mph (3 million km/h). As it does so, it generates a shock wave that slams into the group's intergalactic gas, causing it to emit X-rays. Chandra researchers released the image July 9.

Stephan's Quintet is made up of four spiral galaxies — NGC 7317, NGC 7318a, NGC 7318b, and NGC 7319 — in the process of becoming elliptical galaxies. The large galaxy at the group's bottom left (NGC 7320) is in the foreground and isn't part of the interacting group. Signs of past interactions are also visible in Stephan's Quintet. Most obvious are the tidal tails of debris.

Astronomers observing Stephan's Quintet in infrared radiation (which is lower energy than X-ray radiation) have also seen emission likely caused by the shock wave. It's not visible in optical light, however. — **L. K.**

Citizen scientists help discover a new group of galaxies

Yale astronomers announced a new group of galaxies discovered with citizen scientists' help, not by stargazing but by computer gazing. The galaxies, dubbed the "Green Peas" because of their small, green appearance, were discovered as part of an online project called "Galaxy Zoo," where volunteers have helped classify galaxies in a huge online picture gallery since 2007. The findings will appear in an upcoming issue of *Monthly Notices of the Royal Astronomical Society.*

Out of one million galaxies in the bank, the searchers found only 250 Green Peas. This search is the kind of job that one dedicated astronomer couldn't do in decades, but multitudes of part-time astronomers could accomplish quickly.

The Yale scientists also discovered that the Green Peas, between 1.5 and 5 billion light-years away, create stars faster than usual, about 10 times as many new stars per year than our own Milky Way. That's all the more unexpected given their relative size — about 10 times smaller than the Milky Way and 100 times less massive.

C. Cardamone/SDSS

Round and green. **A newly discovered class of so-called "Green Pea" galaxies (four appear here) may help astronomers learn how early galaxies operated.**

Because such galaxies would have been more normal in the early universe, further research could help guide theories as to how early galaxies formed stars and evolved. — **BILL ANDREWS**

QUICK TAKES

NEW SPIN FOR SATURN
New meteorological data from NASA's Cassini spacecraft show that Saturn rotates in 10 hours and 34 minutes — 5 minutes faster than previously thought.

NASA'S NEW TEAM
On July 15, the U.S. Senate confirmed former astronaut Charles Bolden as NASA's 12th administrator and Lori Garver as deputy administrator.

SPIRAL STARS
Using a new instrument to study 30 nearby galaxies, University of Texas at Austin researchers have confirmed that areas rich in molecular gas create stars at a faster rate.

MAUNA KEA GROWING
On July 21, directors of the Thirty Meter Telescope project announced that Mauna Kea, Hawaii, will be the instrument's future home. The giant scope should be complete in 2018.

DUNES ON THE MOVE
Planetary scientists were surprised to learn that, contrary to popular thought, snow and ice trapped in sand dunes on Earth and Mars cannot keep the dunes from migrating or, in some cases, disappearing.

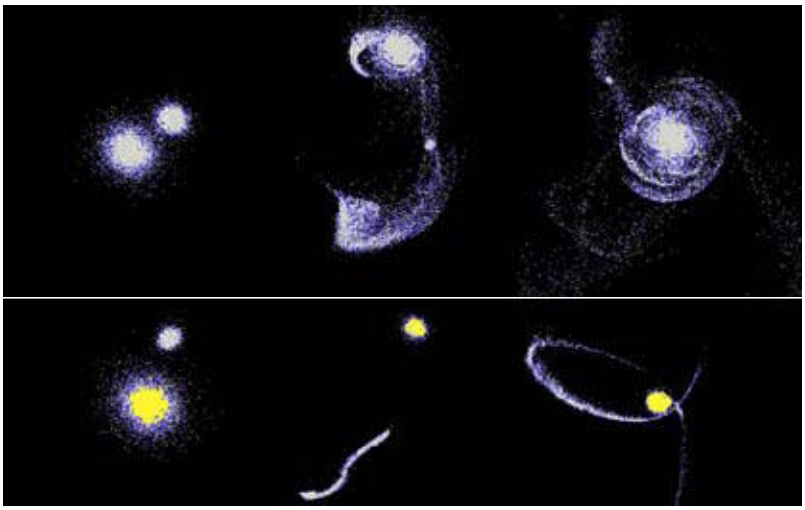
FERMI FINDS
Astronomers using NASA's Fermi Gamma-ray Space Telescope have confirmed for the first time that millisecond pulsars emit gamma rays using a similar mechanism as their normal cousins.

KEEPS GOING AND GOING
On July 23, NASA celebrated the Chandra X-ray Observatory's 10th anniversary. Chandra has doubled its intended 5-year mission and shows no signs of slowing down.

DARK-SKY REWARD
On July 31, the International Dark Sky Association named Borrego Springs, California, an International Dark Sky Community. Flagstaff, Arizona, is the only other town to earn this distinction.

MAGELLAN IS GELLIN'
The Australian government announced in July that it will provide $72.4 million to help fund the 25-meter Giant Magellan Telescope, scheduled for completion in 2019 in Chile.

Canary giant On July 24, Spain's King Juan Carlos I and Queen Sofia dedicated the world's largest telescope, the 10.4-meter Gran Telescopio Canarias, on La Palma in the Canary Islands.



Galactic encounters. Top: A small dwarf galaxy interacts with another galaxy some 100 times more massive. The simulation covers 7 billion years and shows how such collisions effectively strip away stars. Bottom: A simulation of a small dwarf galaxy interacting with the forming Milky Way Galaxy. Elena D'Onghia (CfA)

Galactic dance may strip stars but leave dark matter

Dwarf spheroidal galaxies are small and faint. They do, however, have a high percentage of dark matter — the invisible, mysterious mass that acts as the universe's gravitational scaffolding. For years, astronomers have questioned how these galaxies formed and why they are so dark-matter dominated. Recent research published in the July 30 *Nature* may provide some answers.

A group led by Elena D'Onghia of Harvard used computer simulations to look at two different formation methods. In both, the group assumed all galaxies began with a typical percentage of dark matter. In one case, two dwarf galaxies (where one is about 100 times larger than the other) encountered each other, and in the other a dwarf galaxy encountered the forming Milky Way Galaxy.

D'Onghia and colleagues found that if the smaller galaxy's spin and orbit rotation are in sync with the larger galaxy's spin, the galaxies' gravitational influences are enhanced. This strips away stars but not dark matter. That's because the dark matter particles move on random orbits, not as a disk like luminous matter. The random orbits average out to no net movement. So the gravitational resonance removes luminous matter more efficiently than dark matter, leaving the dwarf galaxy with a high percentage of dark matter.

The group's simulations accounted for stars and did not include gas. However, the astronomers say that the gravitational resonance mechanism will affect both materials within a rotating disk in a similar manner. — **L. K.**

25 years ago in *Astronomy*

November 1984

Barry Parker, now a professor emeritus of physics and astronomy, wrote about the "missing mass" problem in the November 1984 issue of *Astronomy*. Parker described the evidence for dark matter — the mysterious mass that makes up almost 90 percent of the universe's mass. He wrote about the possible candidates and other general aspects of cosmology.

So what could dark matter be? He wrote, "We don't know yet — but hopefully, we will discover the answer in the next few years."

We've come a long way since then, but at the same time we have a long way to go. As explained in this month's cover story, "What do we really know about dark matter?" on page 28, scientists have far more evidence that dark matter exists. But they still have only theories about its nature.

November 1999

10 years ago in *Astronomy*

In the November 1999 issue of *Astronomy*, science writer Robert Zimmerman wrote about potential dangers to Earth in "When Disaster Strikes." Zimmerman began with a discussion of the threat of asteroids and comets. This topic seems especially pertinent after the July Jupiter impact.

Farther from home, Zimmerman discussed dense passing gas clouds, supernovae, and the even more energetic gamma-ray bursts. Any of them could harm the planet's atmosphere and life on Earth. In fact, some astronomers believe that some might "provide explanations for much of Earth's fossil record."

If you think we're safe from destructive events, Zimmerman said, you should think again. — **L. K.**

BRIEFCASE

Most distant supernovae found

A search through archival data from the Canada-France-Hawaii Telescope Legacy Survey, followed by Keck observations, identified the two most distant supernovae yet found. Both exploded roughly 11 billion years ago. The progenitors were likely extremely massive stars that shed some of their mass before exploding. These are called type IIn supernovae. The finding appeared in the July 9 issue of *Nature*. — **L. K.**

Simulations find some early stars were twins

Astrophysicists using supercomputers to simulate the formation of the universe's first star got a surprise — twins. The researchers incorporated primordial gas and dark matter in amounts determined from cosmic microwave background observations. With those ingredients they ran five simulations, each lasting 3 weeks. In one case, the single cloud of matter formed into two stars. The scientists reported their finding in the July 10 *Science*. — **L. K.**

Asteroid upheaval

Astronomers say that some 3.9 billion years ago our solar system's giant planets rearranged themselves. While relocating, they catapulted outer icy objects toward the inner solar system, and many landed in the asteroid belt between Mars and Jupiter. This was the last major event of planet formation. A study published July 16 in *Nature* says this is why the asteroid belt shows such diversity — many of the bodies originated in the outer solar system and were flung inward. — **L. K.**

Warm glow. The Spitzer Space Telescope captured this view of star-forming region DR 22 in Cygnus July 21, some 2 months after the instrument exhausted its coolant. Blue areas are dusty clouds, and orange regions reveal clouds of hot gas. NASA/JPL-Caltech

Spitzer: Warm is good

The infrared-sensitive Spitzer Space Telescope has snapped the first images since it ran out of liquid-helium coolant in mid-May. The July images, taken with two detectors that still function at the telescope's new, warmer temperature, show there's a lot of life left in the 6-year-old instrument.

"The performance of the two short-wavelength channels of Spitzer's infrared array camera is essentially unchanged from what it was before the observatory's liquid helium was exhausted," says Spitzer program scientist Doug Hudgins of NASA Headquarters in Washington. "That means Spitzer's sensitivity at those wavelengths is still roughly the same as a 30-meter ground-based telescope."

Despite the warm-up, Spitzer still operates at a bone-chilling –405° Fahrenheit (–243° Celsius). During its so-called "warm" mission, the telescope will explore distant galaxies, planet-forming disks, and the atmospheres of gas-giant exoplanets turned up by NASA's Kepler mission. — **R. T.**

Gamma-ray bursts are even more mysterious

A recent paper in the July *Astrophysical Journal Letters* concludes that astronomers might be wrong about the origins of gamma-ray bursts (GRBs), the brightest known objects in the universe. Scientists suspect long-duration GRBs start from a giant "fireball" made up of traditional matter, spewed out during black hole formation. But in the paper, Bing Zhang of the University of Nevada, Las Vegas, and Asaf Pe'er of the Space Telescope Science Institute in Baltimore say they've proved that's not the case for at least one GRB.

The group analyzed data from the Fermi Gamma-ray Space Telescope and discovered none of the expected thermal emissions from GRB 080916C. Instead of a fireball, it suggests Poynting flux (energy spikes in electromagnetic fields) got the GRB going.

GRBs proved to be mysterious even before this discovery. They're quite rare, just a few per million years per galaxy, but can release as much energy in a few seconds as the Sun does in its entire lifetime. So far we've only seen GRBs in galaxies billions of light-years away. — **B. A.**

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— Phil Harrington, *Astronomy Magazine*, August 2009

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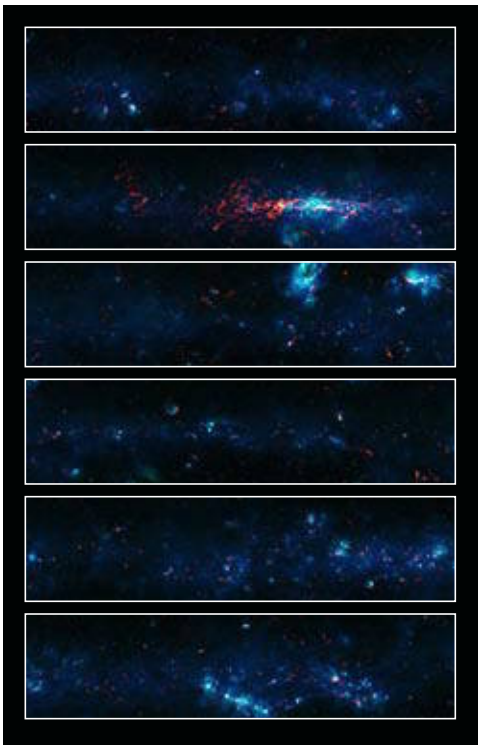

ESO/APEX & MSX/IPAC/NASA

Cold galaxy. **Astronomers mapped the Milky Way's cold dust along 42° of the galactic plane.**

Mapping the Milky Way's cold dust

Astronomers unveiled the largest map of the galaxy's cold dust July 1. Mapping cosmic dust is important because dense knots of dust relate to the birthplaces of new stars. The map reveals thousands of dense clumps — many that had never been seen before. The observations will appear in a future *Astronomy & Astrophysics*.

The international survey extended roughly 42° long and 1.75° high, centered on the galactic plane. Astronomers used the Atacama Pathfinder Experiment (APEX), a 12-meter telescope located at an altitude of about 17,000 feet (5,100m) in the Chilean Andes. Called the APEX Telescope Large Area Survey of the Galaxy (ATLASGAL), the map shows the Milky Way at submillimeter wavelengths (those between infrared and radio).

Not only did ATLASGAL observe dusty birthplaces of stars, but it also looked at the galactic center and bubbles from winds of bright stars. Astronomers will combine these observations with those from the European Space Agency's infrared-sensitive Herschel Space Observatory, which will show finer details than APEX alone. — **L. K.**

Comets not to blame for mass extinctions

University of Washington astronomers have used computer simulations to model the production of long-period comets during the past 1.2 billion years. The research unexpectedly shows that many, if not most, such comets originate in the inner Oort Cloud. Further, the simulations suggest comets don't cause mass extinctions of life on Earth and only rarely provoke minor extinctions. The research appeared July 30 in *Science Express*.

Nathan Kaib and Thomas Quinn examined long-period comets — those that take 200 years or more to orbit the Sun. These comets come from the Oort Cloud, a vast reservoir of icy objects that begins some 1,000 astronomical units (one AU is the average distance between the Sun and Earth) from the Sun and extends out to about 3 light-years.

Comet source. **New computer simulations show that long-period comets, such as C/2001 RX14 (LINEAR) seen here, often originate in the inner Oort Cloud and don't cause mass extinctions of life on Earth.** Mike Solontoi/UW

Astronomers thought most long-period comets originated in the outer part of the Oort Cloud, where passing stars could perturb them enough to send them toward the Sun. But Kaib and Quinn showed that the inner Oort Cloud is a major source of long-period comets that end up in Earth-crossing orbits.

The astronomers then examined how many comets might have struck Earth. They found that no more than two or three major impacts could have occurred during what scientists believe was the most powerful comet shower of the past 500 million years. This event happened about 40 million years ago and caused a relatively minor extinction.

"That tells you that the most powerful comet showers caused minor extinctions and other showers should have been less severe," says Kaib. "So, comet showers are probably not likely causes of mass extinction events." — **R. T.**

ESO/P. Kervella

Gas attack. **An adaptive optics image of the supergiant Betelgeuse reveals a giant plume of gas (right) erupting from the star's surface.**

Betelgeuse blows off steam

Two teams of astronomers used the Very Large Telescope (VLT) in Chile to study the red supergiant star Betelgeuse in unprecedented detail. They found both a vast plume of gas and a huge bubble boiling off the behemoth's surface.

Betelgeuse ranks as one of the biggest known stars, with a diameter almost 1,000 times that of the Sun and a luminosity some 100,000 times greater than our star. Red supergiants shed mass at prodigious rates; Betelgeuse casts off roughly 1 Earth mass of material every year. The new observations provide clues as to how these stars do it.

A team led by Pierre Kervella of the Paris Observatory used an adaptive optics instrument on the VLT to take the sharpest ever portrait of Betelgeuse. The researchers discovered a gaseous plume that reaches from the surface to at least 6 times the star's diameter — a distance roughly equivalent to Neptune's distance from the Sun. "This is a clear indication that the whole outer shell of the star is not shedding matter evenly in all directions," says Kervella.

The second team, headed by Keiichi Ohnaka of the Max Planck Institute for Radio Astronomy in Bonn, Germany, used the VLT Interferometer to probe Betelgeuse in even finer detail. These observations show that atmospheric bubbles as big as the star itself move up and down at speeds of some 25,000 mph (40,000 km/h).

The team suspects these gas motions helped eject the giant plume. Both research groups will report their findings in an upcoming issue of *Astronomy & Astrophysics*. — **R. T.**

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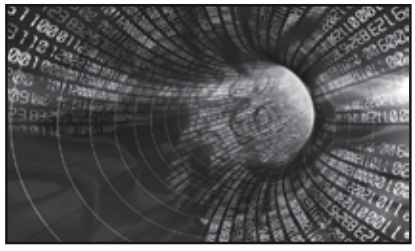

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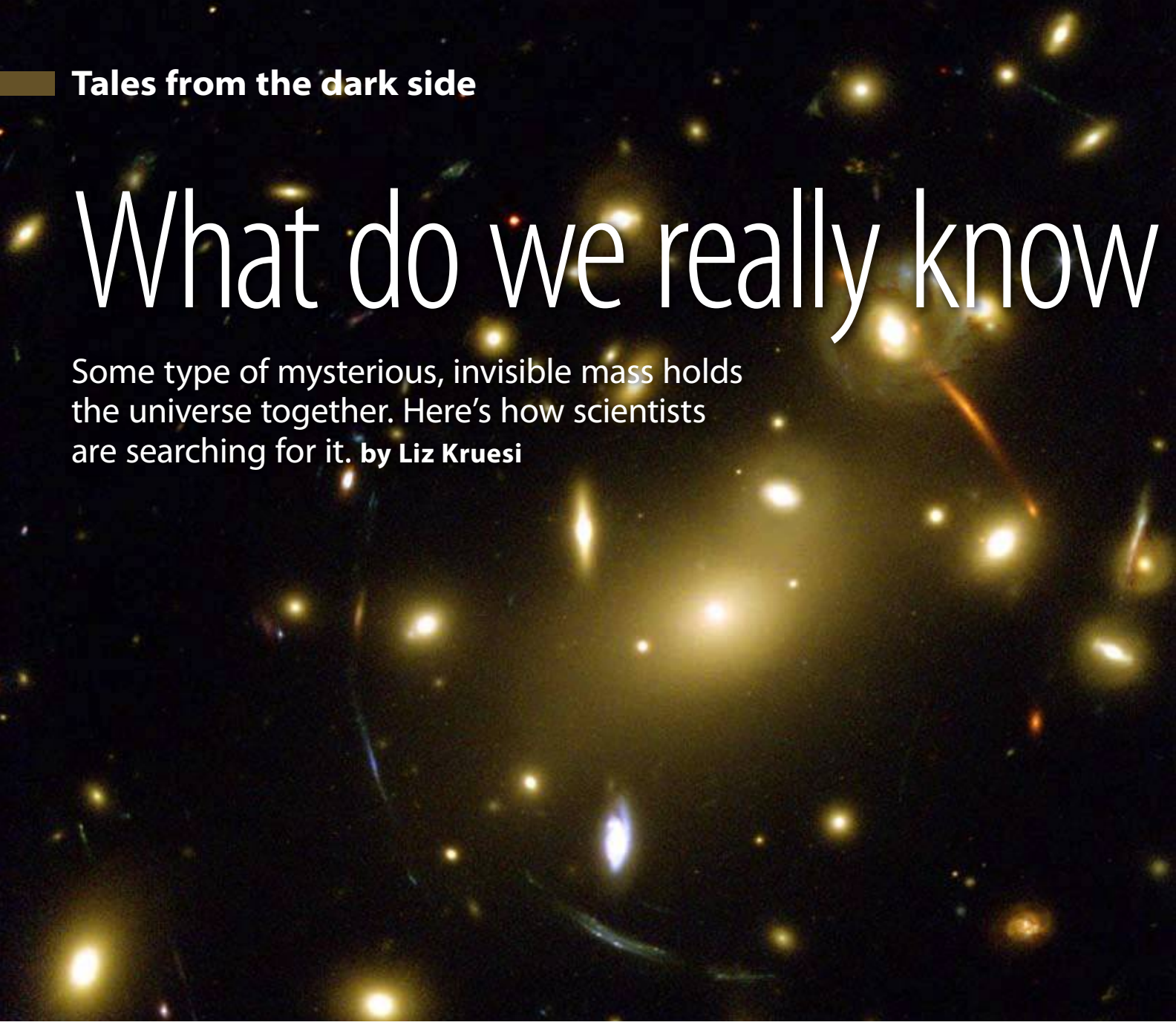
What do we really know

Some type of mysterious, invisible mass holds the universe together. Here's how scientists are searching for it. **by Liz Kruesi**



The universe doesn't abide by "what you see is what you get." In fact, the stuff we see in space — stars, gas, and dust — accounts for only 10 percent of the universe's mass. This visible stuff is ordinary matter, and it's made up of protons, neutrons, and electrons. Scientists call ordinary matter "baryonic matter" because protons and neutrons are subatomic particles called baryons. The other 90 percent of the mass is "dark matter," and it likely surrounds almost every galaxy in the universe.

Dark matter doesn't emit, absorb, or reflect any type of light (so, for example, it doesn't emit X-rays or absorb infrared radiation). This mysterious stuff is therefore invisible, yet astronomers learned it exists because dark matter interacts with ordinary matter through gravity.

Liz Kruesi *is an associate editor of* Astronomy.

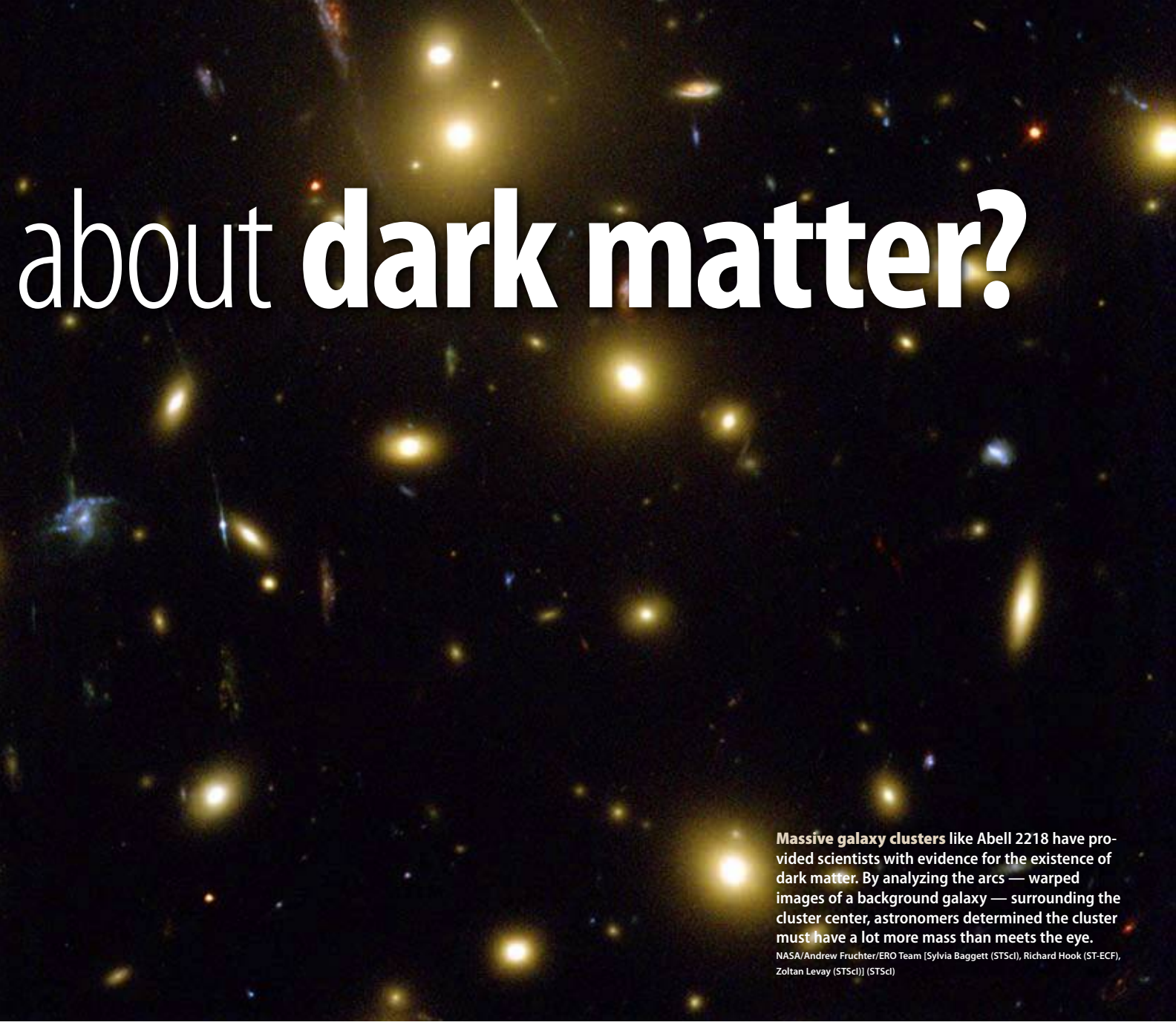
Searching in the dark

Swiss astrophysicist Fritz Zwicky first proposed dark matter's existence in 1933. While studying the Coma cluster of galaxies, he found that the galaxies' collective gravity alone was much too small to hold the cluster together.

The next round of evidence came in the 1970s. Astronomers charted the velocities of stars at various distances from the center of a spiral galaxy and plotted the velocity versus the distance to create a "rotation curve." They expected the velocities to reach a maximum and then decrease farther from the center — but the data showed otherwise. The velocities reach a maximum and then plateau. With velocities so high at the outer edge of galaxies, the stars should fling out of their orbits. But they don't. Some sort of mass scientists can't detect must be holding these outer stars in orbit.

A very massive object — such as a galaxy cluster — can act as a gravitational lens. Some images of regions around galaxy clusters show numerous arcs. Those are background galaxies distorted and magnified by the cluster's gravity.

about **dark matter?**



Massive galaxy clusters like Abell 2218 have provided scientists with evidence for the existence of dark matter. By analyzing the arcs — warped images of a background galaxy — surrounding the cluster center, astronomers determined the cluster must have a lot more mass than meets the eye.
NASA/Andrew Fruchter/ERO Team [Sylvia Baggett (STScI), Richard Hook (ST-ECF), Zoltan Levay (STScI)] (STScI)

Astronomers study the sizes and shapes of those arcs to determine a cluster's mass. By comparing that calculated mass to the mass that comes from only luminous objects (the galaxies), astronomers can determine how much dark matter is in a cluster.

Other evidence has turned up in collisions of galaxy clusters, namely the Bullet cluster. This object is actually the aftermath of two galaxy clusters that collided. Astronomers used a multidetection approach to look at the galaxies, gas, and dark matter. When the clusters collided, the galaxies' stars passed through mostly unaffected because a lot of space exists between the stars. The clusters' hot gas makes up most of their baryonic mass. Ordinary matter interacts through electromagnetic forces. Thus, as matter collides it loses energy as radiation (in the form of X-rays, in this case). The hot gas slows during the collision.

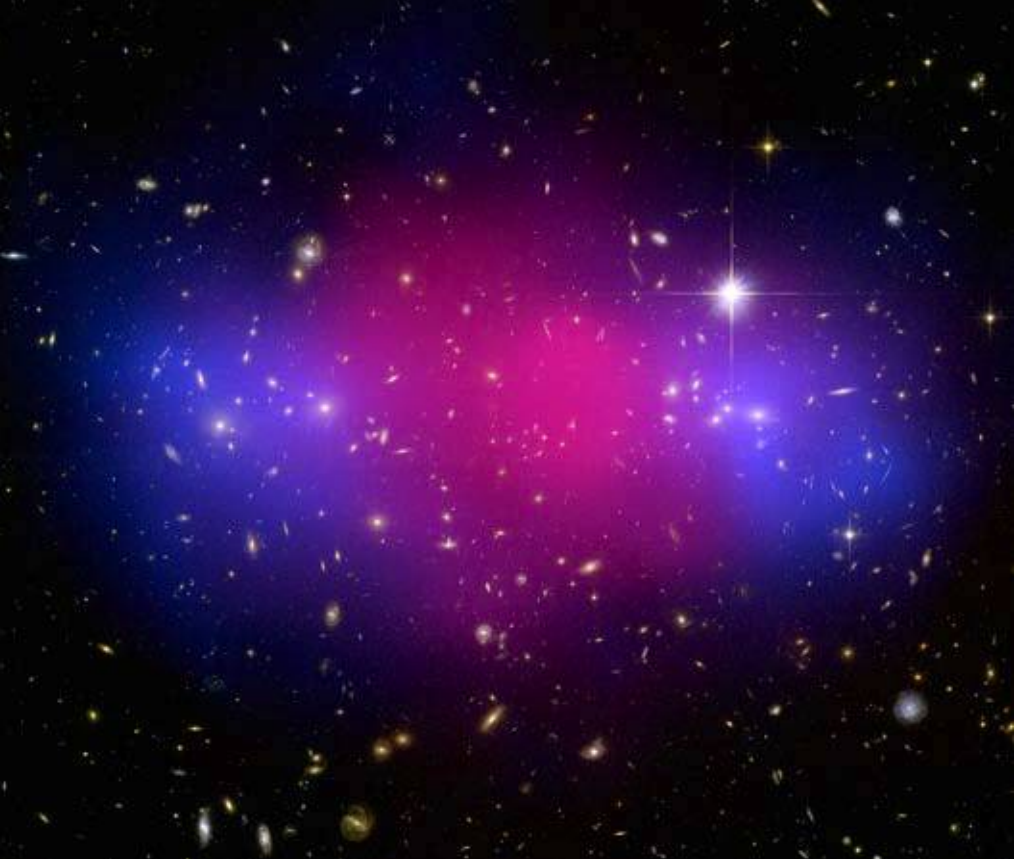
Astronomers use gravitational lensing to indirectly map the dark matter distribution. It turns out that dark matter also passed through the collision unaffected. So images of the Bullet cluster show direct evidence of dark matter.

The evidence is piling up — with 3-D dark matter maps and other detections. Yet mapping the distribution is one thing; knowing the characteristics of this mysterious stuff is another story.

Unlike anything we've seen

For many years astronomers thought dark matter could consist of dead stars, black holes, and other known objects that emit little or no light. They used gravitational microlensing to look for these objects. This technique is similar to gravitational lensing except the foreground object is much less massive. Instead of light bending around the object, the body's gravity magnifies the light from behind it. While astronomers found some of these MAssive Compact Halo Objects (MACHOs), there weren't enough to account for all of the universe's missing mass.

So if dark matter isn't composed of normal objects, then it likely consists of



NASA/ESA/CXC/M. Bradac (University of California, Santa Barbara)/S. Allen (Stanford University)

Two massive galaxy clusters collided to form what's known as the Bullet cluster of galaxies. Ordinary matter — the hot gas, shown in pink — collided, lost energy, and slowed. The clusters' dark matter (shown in blue) interacted little and passed through the ordinary matter.

non-baryonic particles — meaning it's not made up of the same stuff as ordinary matter (protons and neutrons). Astronomers split non-baryonic dark matter into two categories: hot and cold. These titles have nothing to do with temperature. Hot means that early in the universe these particles traveled extremely fast — almost at the speed of light. Cold means that early in the universe the particles traveled more slowly.

How does particle speed relate to dark matter's composition? Slower particles will bunch up into small structures earlier in the universe. Those small structures will eventually collide and merge to form larger ones. Astronomers believe this is how structure develops and evolves in our universe: Smaller structures eventually merge into the massive superclusters we observe today. Astronomers simulate structure evolution with cold dark matter (CDM) and can create models that resemble today's universe.

What is CDM? Scientists aren't sure yet. They have a couple of options that branch from particle physics — but none contrived just to fit into dark matter theories. "Both [options] are generated by particle theories having nothing to do with dark matter," says Juan Collar of the University of Chicago. "However, these hypothetical particles turn out to have all of the properties (mass, abundance, lifetime, probability, and mode of interaction) required to be the dark matter, or at least a fraction of it."

For decades, physicists have worked to explain how the four fundamental physical forces fit together. (These forces are gravitation, electromagnetism, weak nuclear, and strong nuclear.) In the past 30 or so years, they've arrived at supersymmetry theory. This model predicts that each ordinary particle (such as an electron or quark) has a massive "superpartner" (a selectron or squark) that remains undetected.

The leading dark matter candidate is a class of particles that supersymmetry predicts. These particles have mass and interact through the weak nuclear force, but they don't interact through the electromagnetic force. Because these weakly interacting massive particles (WIMPs) interact via the weak force, they can collide with normal atomic nuclei and bounce off them without emitting light or absorbing radiation. The lightest WIMP — called the neutralino — is also the most popular dark matter possibility.

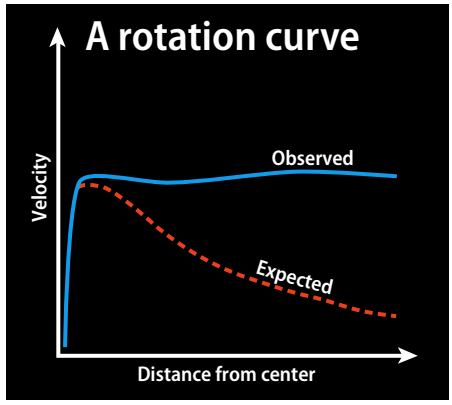
Another common CDM candidate is the axion. The axion is also a hypothetical particle, but it arises from a theory different from supersymmetry. This particle is not a "matter particle" but instead a force carrier, similar to the photon (which "carries" the electromagnetic force). It's much lighter than a WIMP — at least 1 billion times less massive — so the universe would need a whole lot more axions than WIMPs to make up all the invisible matter.

One would expect that with so many CDM particles, WIMPs or axions would be easy to find. But because they don't interact through the electromagnetic force, detecting them pushes scientists' experimental limits.

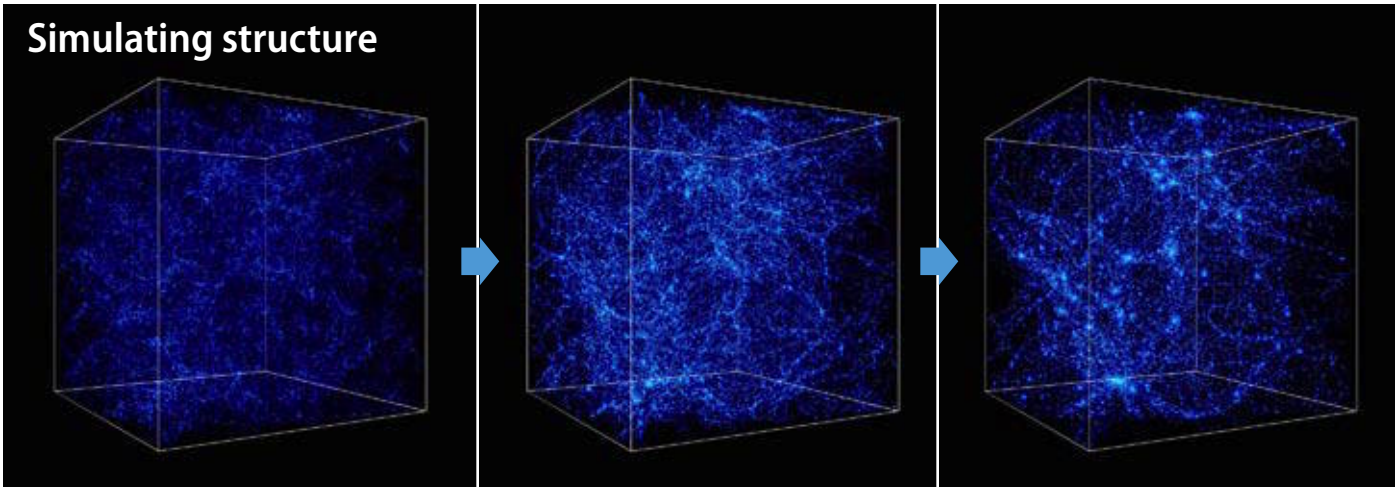
How to hunt CDM

The method used to detect dark matter depends on what type of dark matter (WIMP or axion) scientists pursue. Scientists looking for WIMPs try to directly observe the interaction with ordinary

Astronomers were surprised to find that stars far from a galaxy's core travel at speeds similar to those close in. John Smith



A galaxy's rotation curve compares the disk stars' velocities with their distances from the galaxy's center. *Astronomy*: Roen Kelly



Andrey Kravtsov (U. Chicago)/Anatoly Klypin (NMSU)

The universe's structure seems to evolve as smaller clumps bunch to form larger structures. Astronomers simulate structure evolution with cold dark matter and create models that resemble today's universe. This simulation shows dark matter distribution, where brighter areas represent more dense regions.

matter in a detector. A WIMP can collide with an atomic nucleus and move, or "scatter," the nucleus.

Another method is to indirectly detect dark matter. A WIMP's antiparticle is itself, so if two WIMPs interact, they annihilate each other and produce a shower of secondary particles. Astrophysicists can observe many of these secondary particles — such as electrons, positrons (the electron's antiparticle), gamma rays, and neutrinos.

Scientists' methods to locate axions are "totally different than the direct and indirect detection methods used to look for WIMPs," says Dan Hooper of Fermi National Accelerator Laboratory in Batavia, Illinois. When an axion traverses a detector that has a magnetic field, it will convert into a photon.

Instead of trying to detect CDM particles, some scientists aim to create the particles — WIMPs and axions — in the laboratory. To do this, they have to generate extremely high energies, similar to those shortly after the Big Bang. Only particle accelerators have this ability. After the Large Hadron Collider (the world's largest particle accelerator, located in Switzerland) comes back online late this year, scientists should be able to look for hypothetical particles that may make up dark matter.

Bullying the WIMPs

Astronomers believe a spherical halo of CDM surrounds the luminous galactic disk of the Milky Way (and similar halos encase most other galaxies). As our solar system travels around the galaxy's center,

NASA/ESA/C. Heymans (University of British Columbia, Vancouver)/M. Gray (University of Nottingham, U.K.)/M. Barden (Innsbruck)/the STAGES collaboration/C. Wolf (Oxford University, U.K.)/K. Meisenheimer (Max Planck Institute for Astronomy, Heidelberg)/the COMBO-17 collaboration

Supercluster Abell 901/902 contains hundreds of galaxies. Astronomers analyzed the distortion of some 60,000 background galaxies' shapes to determine the supercluster's distribution of dark matter. They then combined a visible-light image of the supercluster with the dark matter distribution map (shown as a magenta haze).

it moves through this dark matter haze. These particles aren't the only things Earth collides with as it moves through the haze. Incoming high-energy ordinary particles called cosmic rays bombard Earth constantly. Radiation from the Sun and more distant sources do, too.

Scientists seek the WIMPs that may compose the CDM haze by placing most dark matter detectors underground and shielding them to block the detector material from cosmic rays. The key is to be able to block signals from "background noise" and detect when a dark matter particle interacts with the material. And if they can't block all of the noise, they must be able to tell the difference between noise and a WIMP.

Some scientists think about 600 million WIMPs pass through a square meter of Earth's surface every second. But remember that they interact weakly. So how do detectors "see" a WIMP? During a rare collision, the WIMP will transfer some of its energy to an atom's nucleus of the detector material, and, as a result, the nucleus scatters (think of pool balls). The amount the nucleus moves (or "recoils") is related to the WIMP's energy. Scientists detect this recoil a few different ways.

ATIC collaboration

The balloon-borne detector Advanced Thin Ionization Calorimeter (ATIC) found a nearby source of mysterious cosmic rays. The source could be a dark matter cloud.

Crumbs along the trail

A group using a balloon-borne detector last November disclosed a previously unknown source of high-energy electrons (cosmic rays). Cosmic-ray particles tend to lose much of their energy by the time they traverse the galaxy and Earth's atmosphere. So scientists typically detect low-energy cosmic rays near Earth's surface. The high-energy electrons that the Advanced Thin Ionization Calorimeter (ATIC) group found indicate the electrons are coming from a nearby source — within about 3,000 light-years.

By analyzing the electrons' detected energies, scientists can determine the energy the particles had before traversing the atmosphere. That energy matches what scientists expect from the products of a possible cold dark matter particle's annihilation. When two Kaluza-Klein (KK) particles meet, they annihilate each other and produce an electron and its antiparticle, the positron. (ATIC can't tell the difference between electrons and positrons, so its electron detection is a total number of electrons and positrons.) If the detected particles truly are products from KK annihilation, then our solar system may be passing through or near a large clump of KK dark matter.

However, these high-energy electrons could also arise from an undiscovered pulsar or other object. And more recent observations by the Fermi Gamma-ray Space Telescope cast doubt on the ATIC observations.

A group using a different detector — the Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics (PAMELA) satellite — reported in 2008 that it saw a higher-than-expected number of positrons. PAMELA looks at energies lower than ATIC. Some scientists think that PAMELA may have observed positrons from another dark matter particle's annihilation. — *L. K.*

One type of detector uses crystals kept at frigid temperatures (only 0.01 degree above absolute zero). Crystals have a set structure, so when a WIMP collides with an atomic nucleus, the nucleus recoils and rams into surrounding structure. In these collisions, the scattered nucleus transfers some of its kinetic energy and slightly heats the material. The frigidity ensures that the detected vibrations have resulted from only incoming particle interactions. Of course, the scientists will likely detect particles other than just WIMPs. So most WIMP detectors use multiple methods to determine "on an event-by-event basis if what took place looked like a dark matter particle interaction or something more mundane," says Collar.

When a WIMP scatters the atomic nucleus and hits surrounding atoms, it could knock off electrons, therefore "ionizing" these atoms. Certain ionization detectors can measure these loose charges.

In some materials, such as liquid xenon, a light flash will indicate a WIMP. After the scattered nucleus rams into other atoms and frees electrons, the atom emits a light flash called scintillation. Usually if a detector looks for scintillation, it will also hunt for ionization.

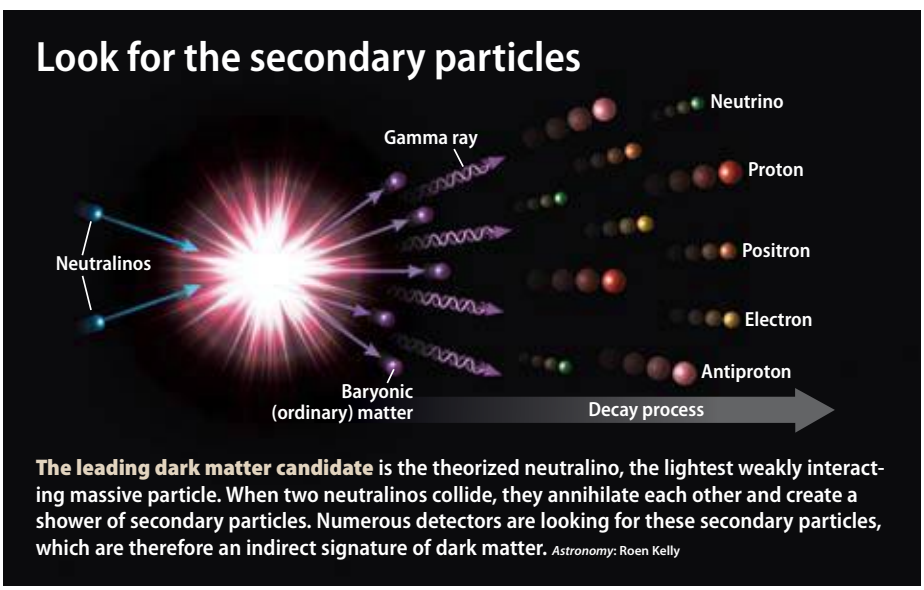
Another approach to the direct search is using a bubble chamber — a glass jar filled with a specific type of liquid. When a WIMP hits an atomic nucleus, it will produce a tiny bubble. Scientists then watch the bubble grow. How it grows depends on whether the interacting particle was a WIMP or a background particle.

A reliable WIMP detection would be if the WIMP signal varied as a result of the time of year. This is because Earth revolves around the Sun. In June, Earth's movement is in the same direction as our solar system's path around the galaxy, so the detected signal should increase. In December, Earth moves in the opposite direction, and scientists should detect a signal some 5 to 10 percent smaller. This signal difference helps distinguish the WIMPs from the background noise because the noise remains the same while the WIMP signal modulates.

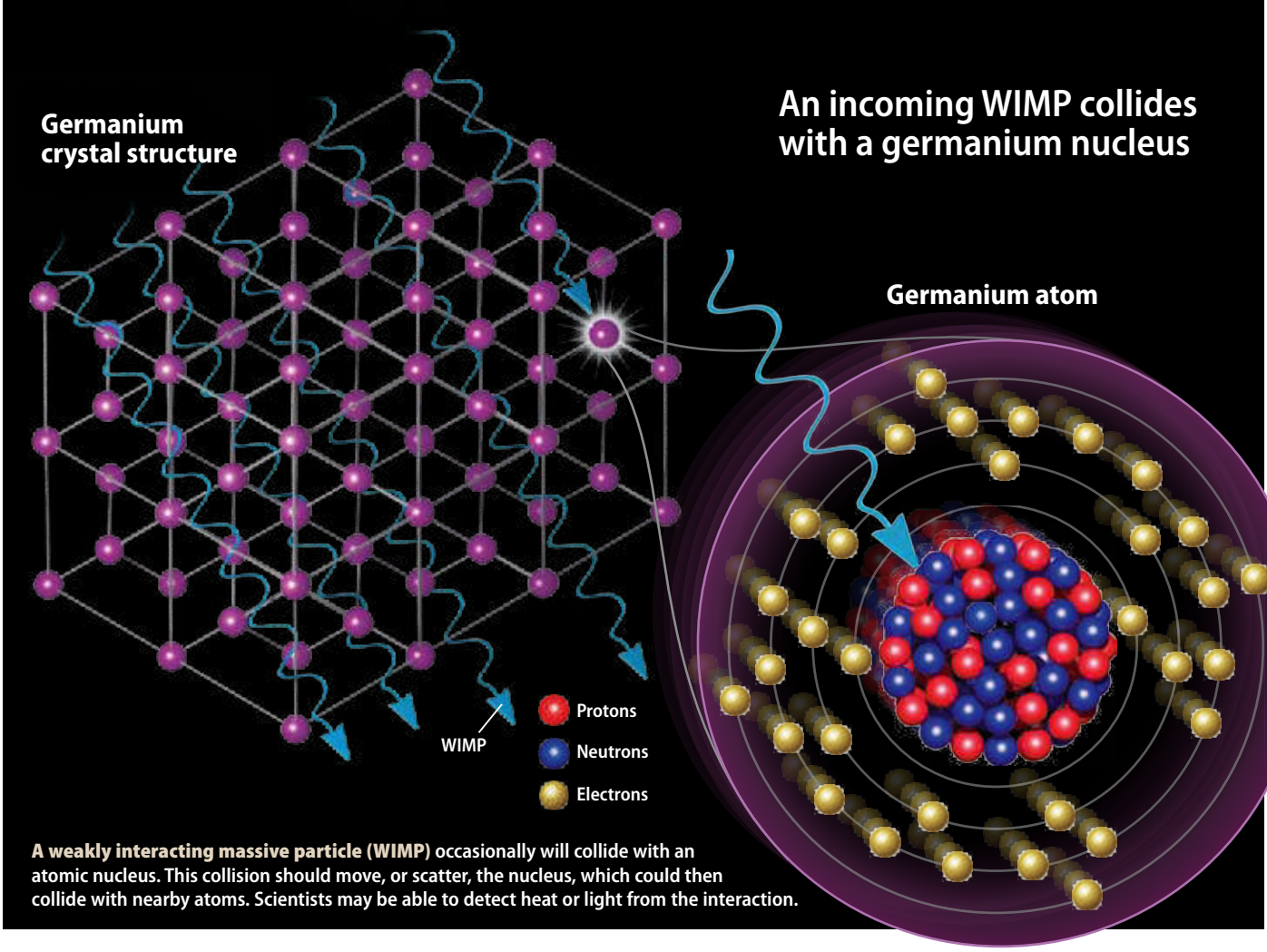
The team of scientists with the DArk MAtter (DAMA) experiment claimed some years ago (and again in 2008) that it found evidence for the existence of WIMPs by looking at this modulation. Unfortunately, DAMA used only one detection method and therefore may not have been able to discriminate between background noise and a WIMP signal. And no other scientific group has repeated DAMA's discovery. In science, if another group can't repeat a finding, then there's a distinct possibility that experimental error and not evidence is responsible.

WIMPy signals

So far, direct searches haven't found WIMPs. Therefore scientists also look for the indirect signature of the dark matter candidates to complement direct searches. Neutralino annihilations should produce electrons, positrons, gamma rays, and neutrinos, along with other particles. Scientists can use certain detectors to look for each product.



The leading dark matter candidate is the theorized neutralino, the lightest weakly interacting massive particle. When two neutralinos collide, they annihilate each other and create a shower of secondary particles. Numerous detectors are looking for these secondary particles, which are therefore an indirect signature of dark matter. *Astronomy:* Roen Kelly



Astronomy: Roen Kelly

A weakly interacting massive particle (WIMP) occasionally will collide with an atomic nucleus. This collision should move, or scatter, the nucleus, which could then collide with nearby atoms. Scientists may be able to detect heat or light from the interaction.

The density of neutralinos (or other WIMPs) must be high in order for these particles to meet up and destroy each other. This typically happens within more massive objects.

A WIMP near the Sun or Earth could collide with an ordinary particle's nucleus. (This is similar to what happens within detector material.) The WIMP will lose energy, and its speed could decrease below the Sun or Earth's escape velocity. If that happens, the WIMP cannot escape the massive object's gravitational hold. The WIMP can collide with another nucleus and so on until it settles into the core of either the Sun or Earth.

At the core, the densities are so high that WIMPs collide and produce secondary particles and radiation. (As mentioned before, neutrinos and gamma rays are two such products.) Several experiments underground — such as Super-Kamiokande in Japan — detect neutrinos.

WIMP collisions aren't the only nearby events that release neutrinos — the Sun produces them. Neutrino detectors can decipher WIMP neutrinos from solar neutrinos because WIMP neutrinos have greater energies. And a larger detector should find more neutrinos (hopefully of the WIMP variety). The next-generation neutrino detector IceCube should help in this search. IceCube is currently being built at the South Pole, and will cover a very large area — a cubic kilometer.

Searches for gamma rays from WIMP annihilations also look promising. The gamma rays should have a specific energy spectrum that depends on how massive the WIMP is. The Fermi Gamma-ray Space Telescope may be able to detect that particular spectrum and offer an indirect observation of dark matter. Says Hooper, "If I had to wager a guess, I would say that the best prospects to detect WIMPs in the near future are with gamma-ray telescopes." A number of ground-based gamma-ray detectors are also on the lookout.

Where's the axion?

A WIMP may be the leading CDM candidate, but it isn't the only one. The axion is also a popular possibility.

An axion detector consists of two parts: a cavity with a magnetic field and an antenna with amplifier. According to theory, as an axion traverses the cavity, it will convert into a microwave photon. The photon's frequency will be proportional to the axion's mass. Scientists, however, aren't sure what the axion's mass is, which means they're unsure what frequency to search for. Using the antenna and amplifier, scientists will scan portions of the microwave region looking for a signal that stands out above the background noise.

Detector sensitivity is slowly getting to where it needs to be to pick out axions — and WIMPs — from background noise. It's not there yet, but scientists, with the help of elegant particle theories, are throwing everything they have at searching for (and hopefully detecting) dark matter.

"Very often in particle physics we have followed such 'natural' prescriptions, only to be surprised by nature," says Collar. With more advanced detectors coming in the next decade or so, cosmologists are sure to get a surprise — whether a hint that they're on the wrong path or a promising detection.

Astronomy The next generation

Beyond 2020, telescopes will be huge, cost-effective, and easy to service — even the ones in space. **by Ray Villard**

The Stellar Imager (SI) is a proposed ultraviolet and visible-light interferometer in space. The "telescope" combines thirty 3.3-foot (1 meter) mirrors in a 0.3-mile-wide (0.5 kilometers) array 932,000 miles (1.5 million kilometers) from Earth. Each mirror directs its light to a common hub, which combines the 30 images, processes the final picture, and transmits it to Earth. SI will study stellar magnetic fields, the mechanisms that create those fields, and the internal structure of the stars around which the fields operate. SI's ultimate goal is to achieve the best possible forecasting of solar activity and how it affects our climate on time scales ranging from months to decades. *Astronomy*: Roen Kelly

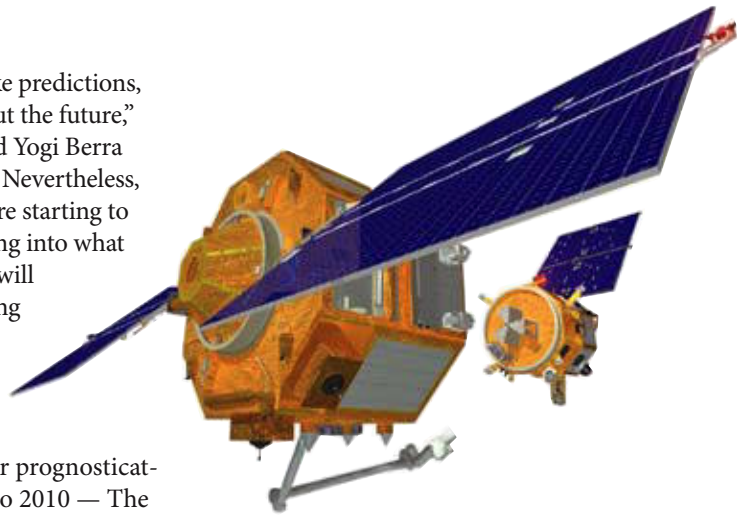
"It's hard to make predictions, especially about the future," baseball legend Yogi Berra once quipped. Nevertheless, astronomers are starting to do some crystal-ball gazing into what types of technology they will need to do groundbreaking research beyond the next decade and into the years between 2020 and 2030.

The big motivation for prognosticating is the upcoming Astro 2010 — The Decadal Survey on Astronomy and Astrophysics. A committee of the National Research Council will conduct this survey in early 2010. This report engages the scientific community to rank a list of astronomical missions and facilities for the next decade. Congress will use the information to decide which new astronomical telescopes and space missions it will fund. The National Academies web site maintains all information related to the Decadal Survey. Find it online under the "Current Projects" section at www.nationalacademies.org.

This upcoming Decadal Survey also will act as a road map to influence NASA's planning for bigger and more ambitious space science missions beyond 2020. Although 10 years away, astronomers must assess the key science frontiers they will pursue, what kinds of telescopes they will need, and what it will cost.

The list of new frontiers astronomers want to tackle includes probing the distant universe for the first stars, determining the nature of dark energy, seeing how the first black holes formed and evolved, studying the growth of planets in circumstellar disks, and looking for life on Earth-mass exoplanets orbiting in habitable zones around nearby stars.

The year 2020 and beyond seem a long way off when thinking about supertelescopes. But planning for the Hubble Space Telescope began nearly 20 years before NASA launched it in 1990. Similarly, astronomers started to plan for Hubble's successor, the James Webb Space Telescope, in the mid-1990s. It won't launch until 2014.



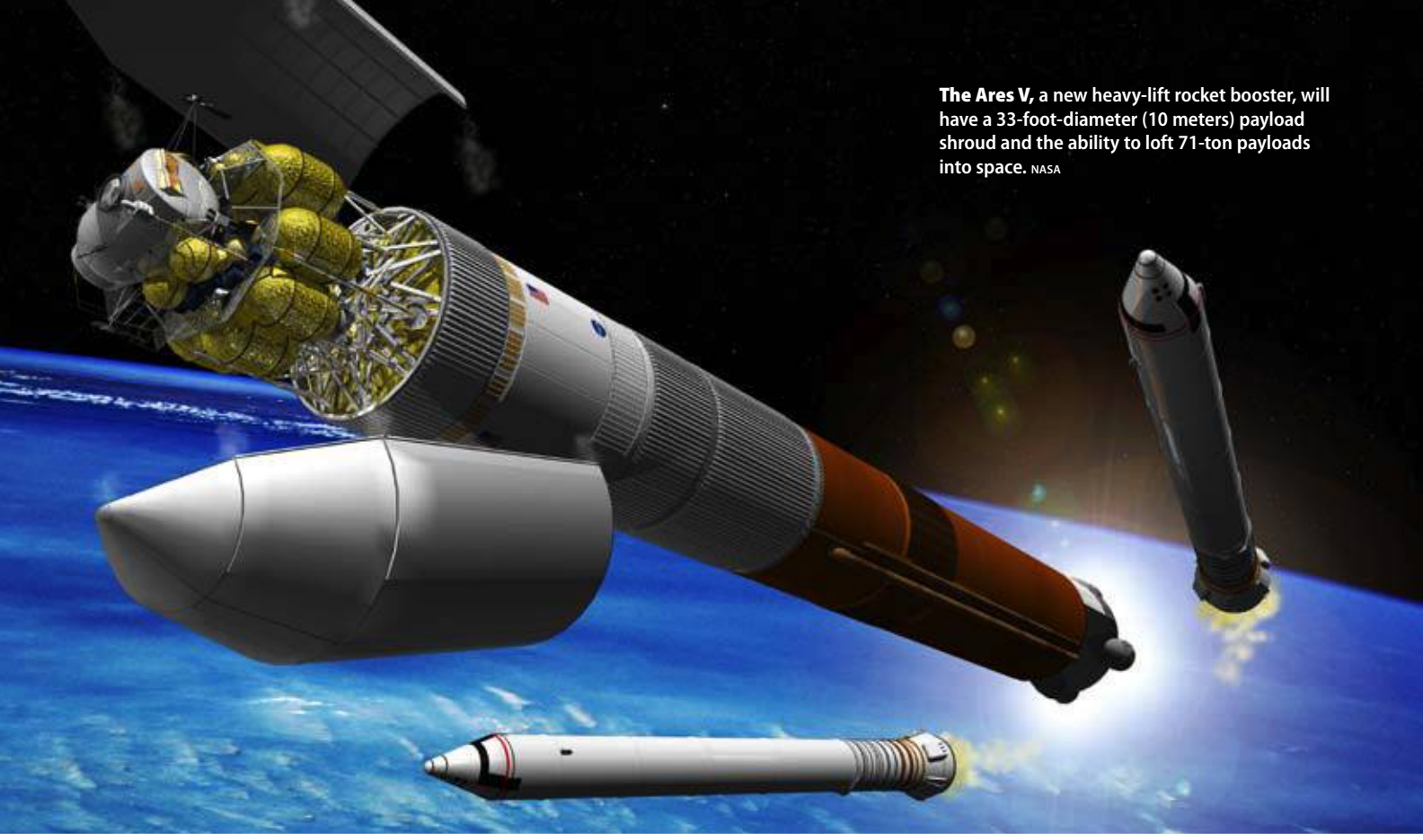
Military space experiments may lead the way past 2020. In June 2007, the Department of Defense conducted a successful test mission with its Defense Advanced Research Projects Agency (DARPA) Orbital Express System. The exercise used two robotic spacecraft. BOEING

What's clear in the crystal ball is that ambitious projects will need to piggyback on a robust human space program. Large space telescopes will require rockets that can lift tens of tons of payload inside a trailer-truck-sized payload shroud. And such boosters will launch not only science applications but also human crews and equipment to the Moon and possibly beyond. We never would have had the Hubble Space Telescope if it weren't wed to the space shuttle program and the concept of space servicing by astronauts.

Technology drivers

Despite the realization of powerful observatories like the Keck telescopes atop Mauna Kea in Hawaii, the Large Binocular Telescope on Mount Graham in Arizona, and the Very Large Telescope array in Chile, astronomers are still photon-starved. Major breakthroughs in astronomy require ever-larger apertures that yield greater sensitivity and resolution.

The next decade will see a new generation of gigantic telescopes. The Giant Magellan Telescope at Las Campanas, Chile, will have the resolving power of an 80-foot (24.5 meters) mirror. The Thirty Meter Telescope will operate either in Chile's Atacama Desert or atop Mauna Kea. And astronomers have scheduled the 42-meter European Extremely Large Telescope for first light in 2018. These behemoths will push deep into the universe to analyze radiation from some of the earliest known galaxies. "Eighty-five



The Ares V, a new heavy-lift rocket booster, will have a 33-foot-diameter (10 meters) payload shroud and the ability to loft 71-ton payloads into space. NASA

percent of the universe's history took place within the first billion years after the Big Bang," says Matt Mountain, director of the Space Telescope Science Institute in Baltimore.

Computer-driven adaptive optics (that correct for atmospheric turbulence) will continue to improve the performance of ground-based observatories. Costing under $1 billion each, these immense telescopes of the future will be significantly cheaper than space observatories. Such instruments also will be easier to repair and upgrade, and they will serve as huge light buckets for detailed spectroscopy (the breaking of light into its component colors) of faint objects.

Despite tremendous improvement in ground-based telescopes, space astronomy has "enormous and compelling advantages," says Steven Beckwith of the University of California system. The entire electromagnetic spectrum is accessible because there is no atmospheric absorption, the sky background is orders of magnitude darker, and images have pristine diffraction-limited sharpness over a wide field of view. What's more, image clarity remains stable over long time periods, a performance characteristic that is crucial for brightness measurements of faint objects or viewing objects in crowded fields.

"Almost all technological breakthroughs that will change the nature of space astronomy will be developed for other customers," Beckwith emphasizes. Astronomers will continue to depend on emerging technologies from bigger research and development budgets than NASA's: the U.S. armed forces and commercial aerospace businesses. The Hubble Space Telescope is nearly a clone of the KH-11 military surveillance satellites developed in the 1970s.

Astronomers aren't the only scientists interested in placing large apertures into space.

Astronomers aren't the only scientists interested in placing large apertures into space. Earth scientists have developed concepts for large millimeter or submillimeter arrays to operate in the 22,236-mile-high (35,786 kilometers) geosynchronous Earth orbit, in which a satellite can hover over the same spot on Earth. Future surveillance satellites may be stationed on this high ground, too, which will enable them to scan larger regions of Earth's surface and make them less susceptible to anti-satellite weapons.

Earth science and surveillance areas will drive research and development on large, deployable, lightweight mirror structures. Engineers are designing a foldable 2-meter telescope to fit inside the 1.3-meter-diameter payload section of a Pegasus aircraft-launched rocket. More advanced concepts have hexagonal mirror segments stacked like tabletop beverage coasters inside a long, skinny payload shroud.

Deployable, multi-segmented arrays also will drive advances in mirror wavefront sensing and control. Advanced fabrication techniques and materials will yield ultra-lightweight mirrors without

Ray Villard *is the news director for the Space Telescope Science Institute in Baltimore.*

the need for time-consuming and expensive mirror grinding and polishing.

Retrieving, processing, and storing huge amounts of astronomical data will continue to follow Moore's Law (which says that computer processing power doubles every 2 years) through 2020. Also, ever-larger cameras will reach gigapixel proportions. Reconnaissance satellite technology will drive onboard image processing. That advance will economize the amount of data coming to Earth from immense detector arrays.

Piggybacking on NASA's return to the Moon

"Human space exploration and space science are joined at the hip," says Jim Crocker of Lockheed-Martin Corporation. Scientists recognized the adaptability of human spaceflight vehicles for multiple missions early during the Apollo Moon program. The Skylab space station, with its Apollo Telescope Mount solar observatory, was the first scientific spin-off using the immense lift capabilities of the Saturn V Moon rocket.

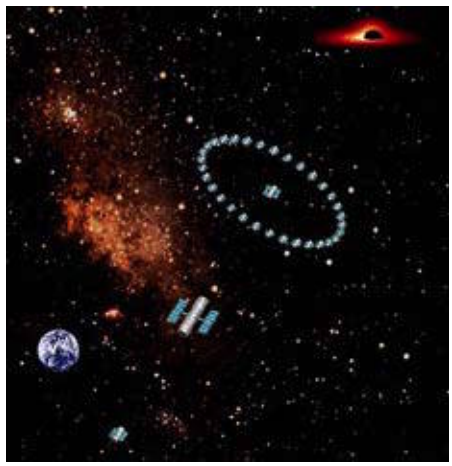
The planned Ares V, a brawny, new, heavy-lift rocket not seen since Apollo's glory days, will have a 33-foot-diameter (10 meters) payload shroud and the ability to loft 65-ton payloads beyond the Moon. Astronomers are salivating at the potential for placing Keck Observatory-sized telescopes 932,000 miles (1.5 million kilometers) away at the Earth-Sun Lagrangian 2 (L2) point, a gravitationally stable "parking lot" for observatories.

If NASA continues with its plans to return humans to the Moon during the 2020s, it also will put in place a new infrastructure for building and servicing large space telescopes. Servicing allows for more robust spacecraft with better risk tolerance.

Astronauts or even robots can upgrade instruments and replace electronic subsystems and propellant consumables. Servicing could extend the lifetime of a multi-billion-dollar large-aperture space telescope 20 years or more. We've already demonstrated this with Hubble.

Military and commercial space experiments are a step ahead in demonstrating this concept. The Defense Advanced Research Projects Agency (DARPA) Orbital Express System conducted a successful rendezvous, docking, and autonomous refueling exercise using two robotic spacecraft in June 2007.

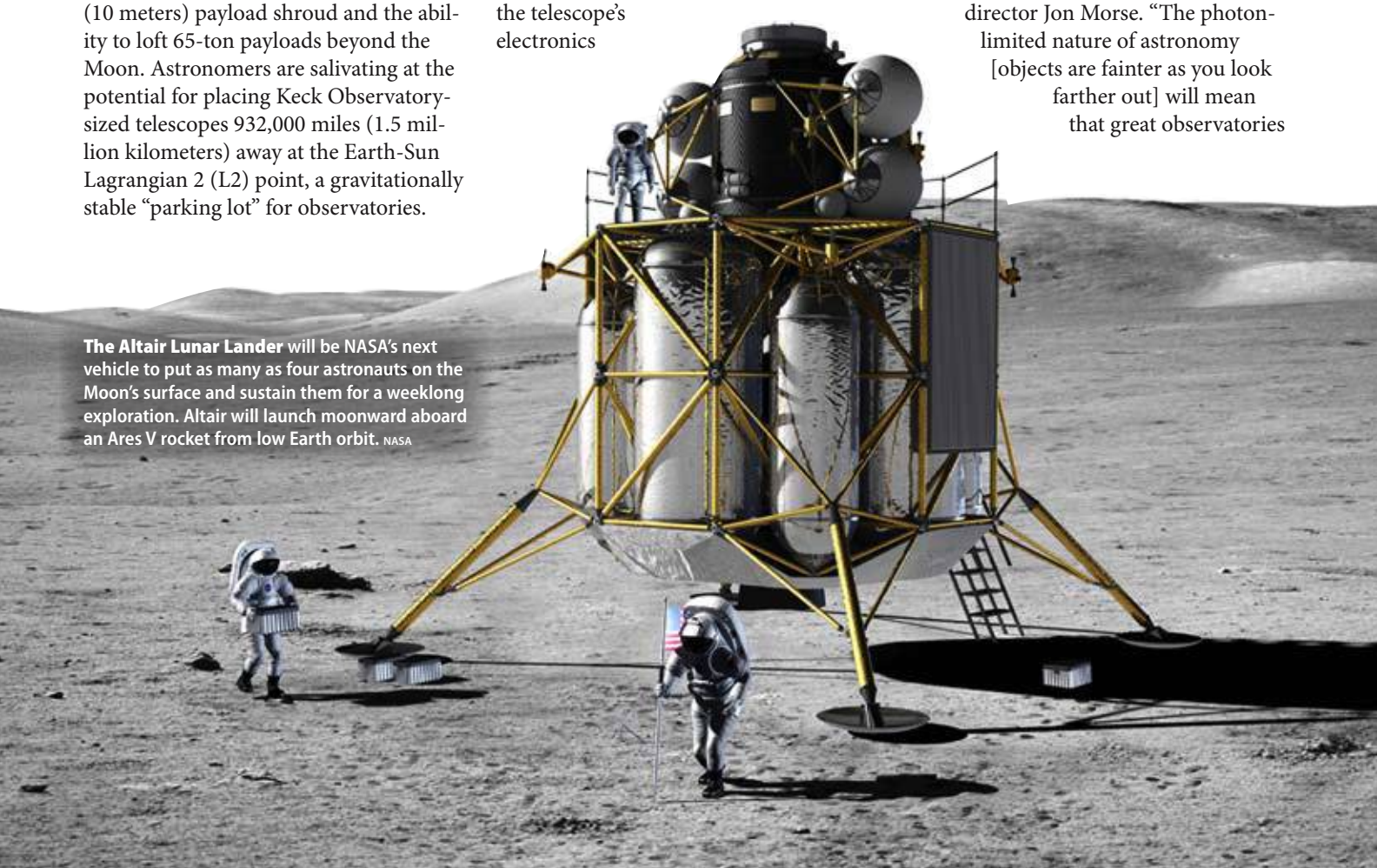
Space telescopes beyond 2020 would not necessarily have screws and bolts to work loose, but something more modular and robot-friendly. One concept, called the boxcar approach, would be to have a free-flying "black box" simply dock with the telescope's electronics module, plug in, and take over for failed power supplies, circuit boards, and other components. This "plug 'n' play" architecture would allow scientists to swap out entire instruments remotely.



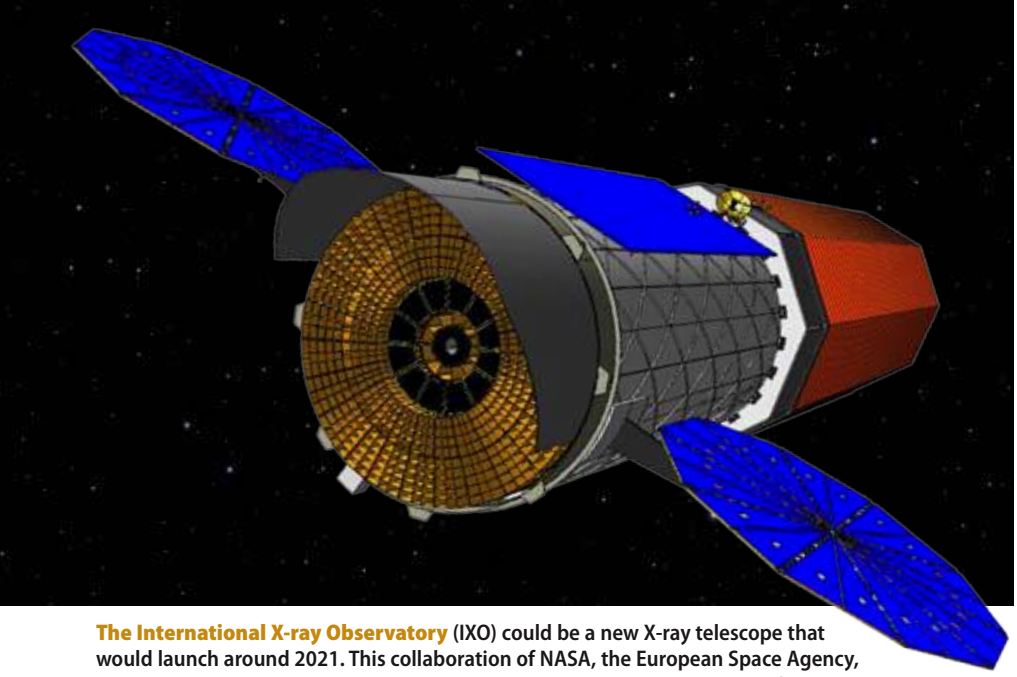
The Micro Arcsecond X-ray Imaging Mission (MAXIM) would have an ambitious goal, if approved: to image the event horizons (boundaries beyond which matter and light cannot escape) around black holes, which would help scientists test Einstein's general theory of relativity. NASA

Budget for a balanced portfolio

Our future space science program must diversify, states NASA's astrophysics director Jon Morse. "The photon-limited nature of astronomy [objects are fainter as you look farther out] will mean that great observatories



The Altair Lunar Lander will be NASA's next vehicle to put as many as four astronauts on the Moon's surface and sustain them for a weeklong exploration. Altair will launch moonward aboard an Ares V rocket from low Earth orbit. NASA



The International X-ray Observatory (IXO) could be a new X-ray telescope that would launch around 2021. This collaboration of NASA, the European Space Agency, and the Japan Aerospace Exploration Agency would study black holes, the formation and evolution of galaxies, and the universe's large-scale structure. Goddard Space Flight Center

get harder to make, meaning longer development times."

Morse estimates that NASA's space astrophysics program can afford one $2–4 billion general-user "flagship" observatory per decade (like the James Webb Space Telescope). Within the same time span, two to four medium-class missions with more specific science goals (such as the proposed Joint Dark Energy Mission to probe the behavior of dark energy over cosmic time), and three to five smaller Discovery-class missions (like the Kepler mission to search for transiting exoplanets) are possible.

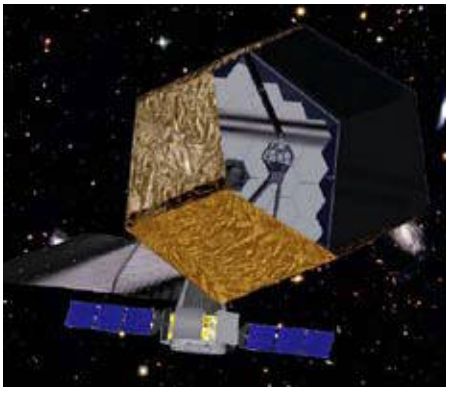
The astronomical community at large is wrestling with balancing its aspirations for space-science missions with the realities of NASA's astrophysics budget of approximately $1.5 billion per year. Already stuck in a backup line on the space astrophysics "expressway entry ramp" are such ambitious missions as the International X-ray Observatory (IXO), a powerful successor to the Chandra X-ray Observatory, and the Laser Interferometer Space Antenna (LISA), which could usher in a whole new realm of astrophysics: gravitational-wave detection.

Given the demand for missions and the monetary constraints, Morse says that much more effort than before will have to go into precisely budgeting a mission's technical development cost. The more technical unknowns, the less likely the mission will be approved.

Some of the space observatories that could compete for funding after 2020 are Advanced Technology Large Aperture Space Telescope (ATLAST), an 8- to 16-meter ultraviolet, visible-light, and infrared observatory having 5 times Hubble's resolution; Generation-X, which will probe the early universe with 1,000 times the collecting area and 5 times the resolution of the Chandra X-ray Observatory; and Single Aperture Far-Infrared Observatory (SAFIR), a 10-meter telescope with 100 times the sensitivity of the Spitzer Space Telescope.

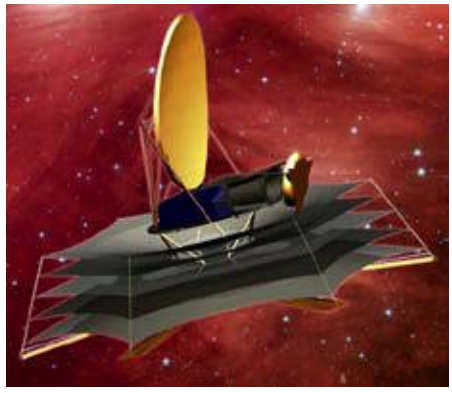
Even more ambitious programs would require smaller telescopes flying in formation that take advantage of the space environment to link together and create, in essence, a telescope with much better resolution. This would yield immense "dilute aperture" telescopes with baselines miles across. "Multiple spacecraft observatories are inevitable; they uniquely enable fundamental new science," says Webster Cash of the University of Colorado at Boulder.

For example, the Stellar Imager (SI) would be a cluster of free-flying mirrors that would map the surfaces of stars with more than 200 times Hubble's resolution. The Micro Arcsecond X-ray Imaging Mission (MAXIM) would resolve a black hole's tiny event horizon (the boundary beyond which matter and light cannot escape). One of the largest arrays would be The Big Bang Observer, a widely separated constellation of clusters of LISA-like gravitational-wave detectors. Sampling the longest wavelength gravita-

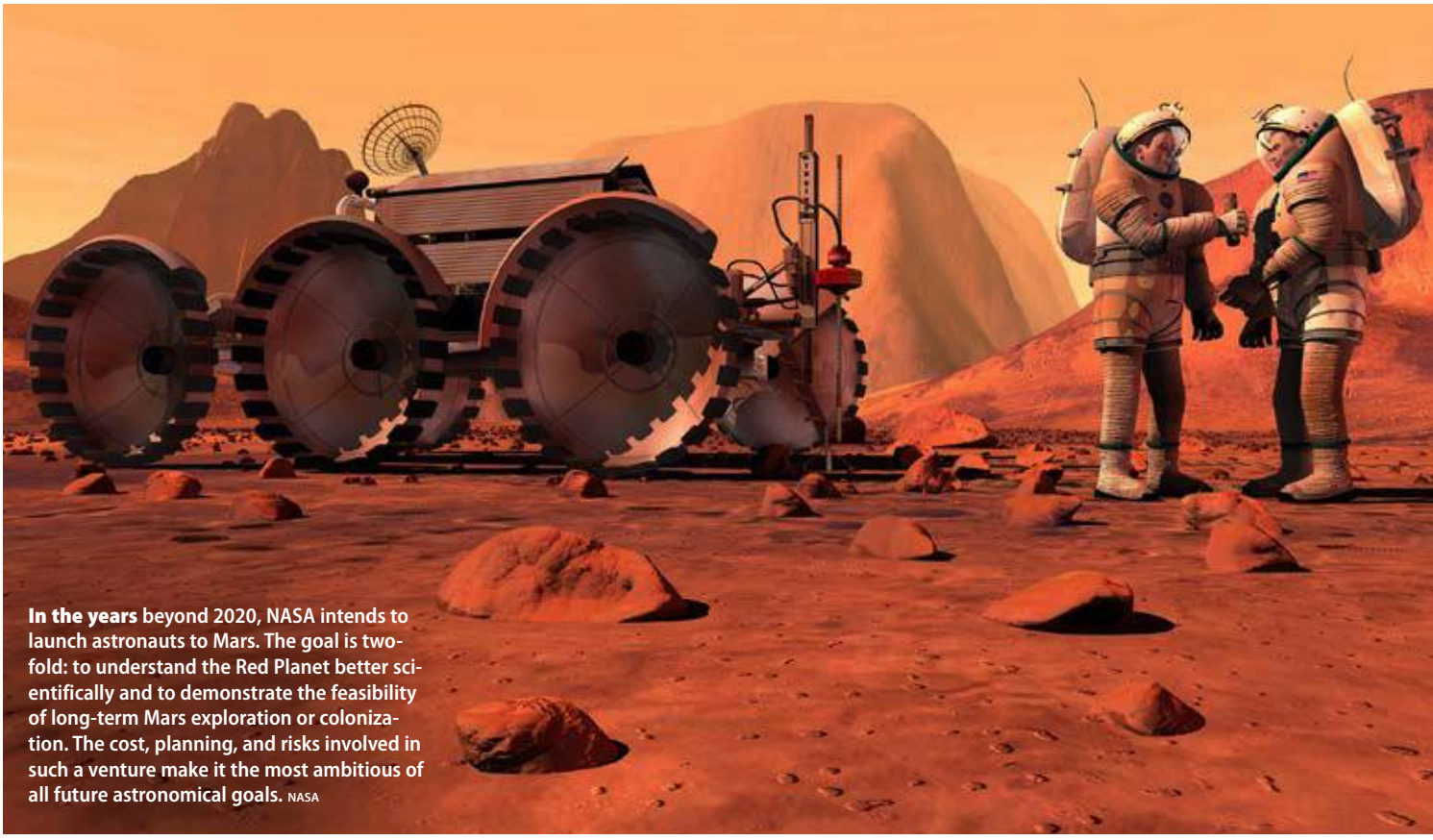


One space observatory planners are considering is the Advanced Technology Large Aperture Space Telescope (ATLAST). This telescope will have a mirror up to 55 feet (16.8 meters) in diameter to study objects emitting ultraviolet and visible light. ATLAST will have 5 times the resolution of the Hubble Space Telescope. STScI

Generation-X will have the sensitivity to probe the universe around the time the first galaxies formed. X-ray imaging of faint objects demands a large collecting area and high angular resolution. The Gen-X array offers 1,000 times the collecting area and 10 times the resolution of the Chandra X-ray Observatory. NASA



Infrared astronomy will take a giant leap forward in the 2020 decade if the Single Aperture Far-Infrared Observatory (SAFIR) obtains approval. This cryogenic 10-meter infrared space telescope would have greater resolution and 100 times the sensitivity of the Spitzer Space Telescope. NASA



In the years beyond 2020, NASA intends to launch astronauts to Mars. The goal is two-fold: to understand the Red Planet better scientifically and to demonstrate the feasibility of long-term Mars exploration or colonization. The cost, planning, and risks involved in such a venture make it the most ambitious of all future astronomical goals. NASA

tional waves would provide a "cosmic ultrasound" from the inflationary period, a time shortly after the Big Bang when, according to some theories, the universe expanded exponentially.

Inspiring a new generation

But these lofty ideas are tethered to cold, hard funding realities. "Simply saying that new telescopes will open up 'discovery space' is too ill-defined to justify billions of dollars in the current climate," says Steven Kahn of the Kavli Institute for Particle Astrophysics and Cosmology at Stanford University.

"Answering specific questions might work if the questions are both sufficiently profound and sufficiently accessible to the public," says Kahn.

Arguably, the search for life on other planets trumps all other questions. "It would have deep philosophical implications affecting our view of our place in the universe," says Kahn.

Exoplanets will be big business in the 2020 decade. Astronomy in the 1600s focused on the solar system's five known planets; in the 1700s, deep-sky objects called "nebulae"; in the 1800s, stars; in the 1900s, galaxies and cosmic evolution. Based on current research, it's a solid bet that the first half of the 21st century will put us face to face with inhabited planets.

In a few years, NASA's Kepler observatory, now scrutinizing 100,000 stars in Cygnus, will yield a statistical estimate of the number of earthlike planets in our galaxy. If the Kepler percentage is high, then telescopes of the next decade will conduct a search for nearby earthlike planets within tens of light-years.

It's a solid bet that the first half of the 21st century will put us face to face with inhabited planets.

But it won't be until at least 2028 before a 16-meter optical space telescope could perform detailed follow-up on as many as 1,000 earthlike planets within 30 light-years. Its light-gathering power would allow for polarimetric and photometric observations, which would determine the presence of oceans, ice, and clouds. Precision spectroscopy would look for unusual abundances of atmospheric gases like oxygen and methane that could indicate the actions of life.

Do astronomers today have "2020 foresight" of what's in store in the coming decades? Or will discoveries, technological breakthroughs, and geopolitical events ultimately sweep astronomers into an even more unpredictable future?

Many new frontiers have opened between Hubble's planning in the 1970s and today: dark energy and the accelerating universe, gamma-ray-burst sources, supermassive black holes, exoplanets, cosmic evolution, and the Kuiper Belt population, to mention a few. "It is not really necessary to look too far into the future; we see enough already to be certain it will be magnificent," wrote aeronautics pioneer Wilbur Wright a century ago. "Only let us hurry and open the roads."

Learn more about the Altair Lunar Lander at www.Astronomy.com/toc.

The Sky this Month

Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

November 09

Mars grows bright

November witnesses the start of the biennial Mars observing frenzy. The Red Planet brightens noticeably and becomes a fine object for viewing through a telescope after midnight.

For an excellent warm-up, target Jupiter, which remains visible for several hours after sunset. The other giant planets are on view, as well: Uranus and Neptune in the evening and Saturn before dawn. Brilliant Venus joins Saturn in the chilly morning sky.

The early setting Sun provides long evenings to enjoy autumn's celestial wonders. And **Jupiter** has to be near the top of any observing list this year. At magnitude –2.4, the giant planet outshines every other evening object except for the Moon, which slides through in early and late November. (On the 23rd, a waxing crescent Moon stands 4° above Jupiter.)

Jupiter lies due south and at its highest point in the sky as evening twilight descends. The planet remains above 30° altitude until 8 P.M. local time during November's first week, but only until 6:30 P.M. by month's end.

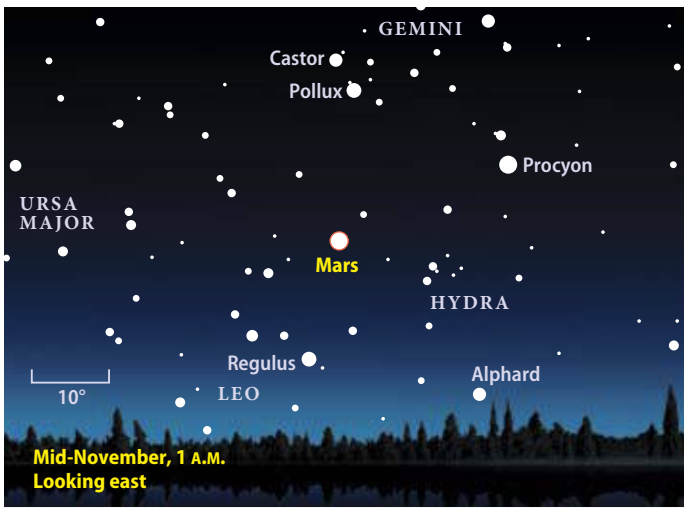
Earth's atmosphere tends to be turbulent right after sunset, which limits the detail you can see through a telescope. And Jupiter's lower altitude in late evening also adversely affects the view. Still, you should find many moments when our atmosphere settles down and the jovian disk comes into sharp focus. Grab as many opportunities as you can to observe the planet now — it will set even earlier next month.

Even a small telescope delivers good views of Jupiter and its four bright Galilean moons. The planet's disk spans 40" at midmonth and should show two parallel dark cloud belts, one on either side of the equator. Under good seeing conditions, you may see several fainter belts.

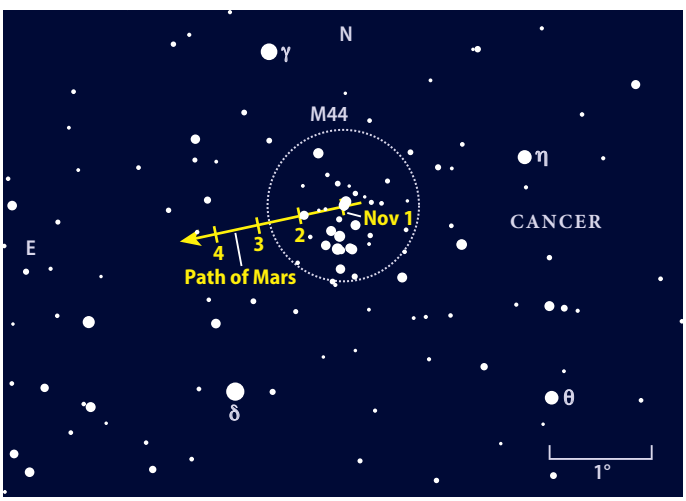
Jupiter resides among the background stars of Capricornus. It passes 0.4° north of Iota (ι) Capricorni November 3. You won't confuse this star for one of the planet's moons, however. The moons all orbit in Jupiter's equatorial plane while the star lies due south of the planet. Also, the 4th-magnitude star shines brighter than any of the moons.

The moons' orbital cycles offer observers a constantly changing attraction. More often than not, you'll see all four moons. On occasion, however, Jupiter hides one or two (for example, on November 21). Sometimes, a moon passes in front of Jupiter and casts its shadow onto the

— *Continued on page 45*



The Red Planet returns to prominence this month, rising before midnight and gleaming in the morning sky. *Astronomy:* Roen Kelly



Mars passes through the heart of the Beehive star cluster (M44) in early November. Binoculars will provide the best views. *Astronomy:* Roen Kelly

40 Mars gleams before dawn
45 Meteor watch
45 Rising Moon
46 When to view the planets
46 Saturn's moons on parade
46 Comet search
47 Locating asteroids
47 The Moon meets the Pleiades

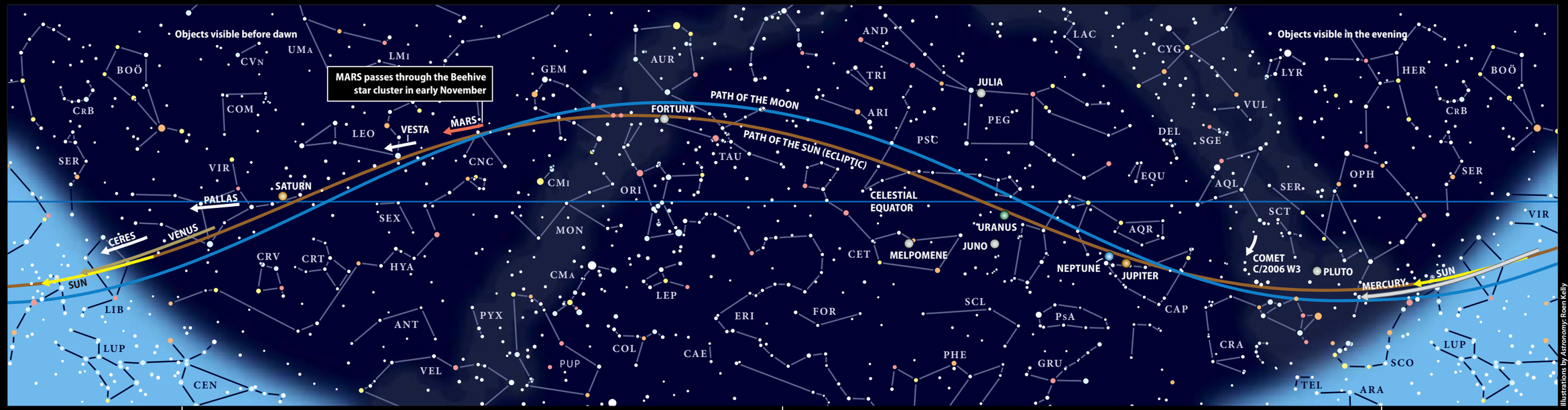
Visible to the naked eye
Visible with binoculars
Visible with a telescope

Planets in November 09

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine

Path of the planets



Illustrations by Astronomy: Roen Kelly

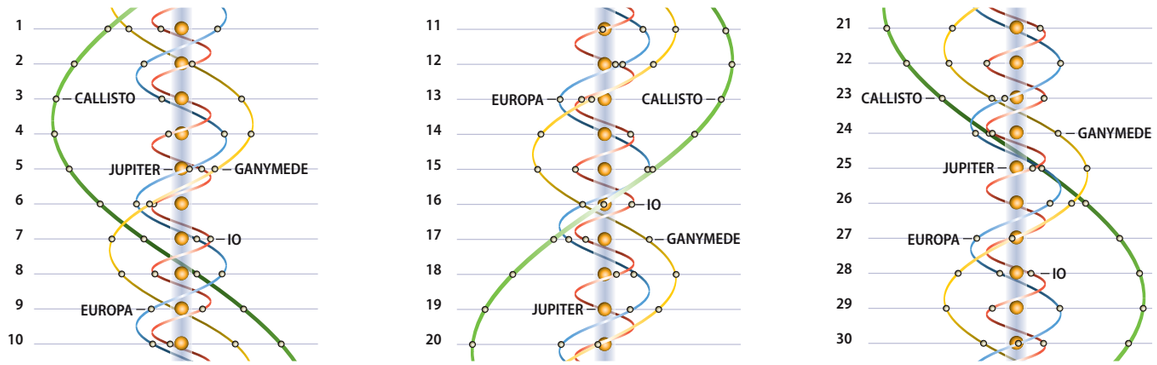
MOON PHASES

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown at 0h Universal Time.

PLANETS	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	November 30	November 15	November 15	November 15	November 15	November 15	November 15	November 15	November 15
Magnitude	–0.5	–3.9	0.2	8.6	–2.4	1.1	5.8	7.9	14.1
Angular size	5.0"	10.2"	8.7"	0.4"	39.6"	16.5"	3.6"	2.3"	0.1"
Illumination	93%	97%	89%	100%	99%	100%	100%	100%	100%
Distance (AU) from Earth	1.337	1.640	1.073	3.640	4.983	10.050	19.584	29.999	32.499
Distance (AU) from Sun	0.445	0.721	1.581	2.669	5.015	9.461	20.097	30.026	31.739
Right ascension (2000.0)	17h21.6m	14h26.6m	9h02.6m	14h54.1m	21h26.1m	12h08.9m	23h34.3m	21h44.2m	18h06.5m
Declination (2000.0)	–25°15'	–13°11'	18°52'	–11°30'	–16°09'	1°19'	–3°37'	–14°03'	–18°13'

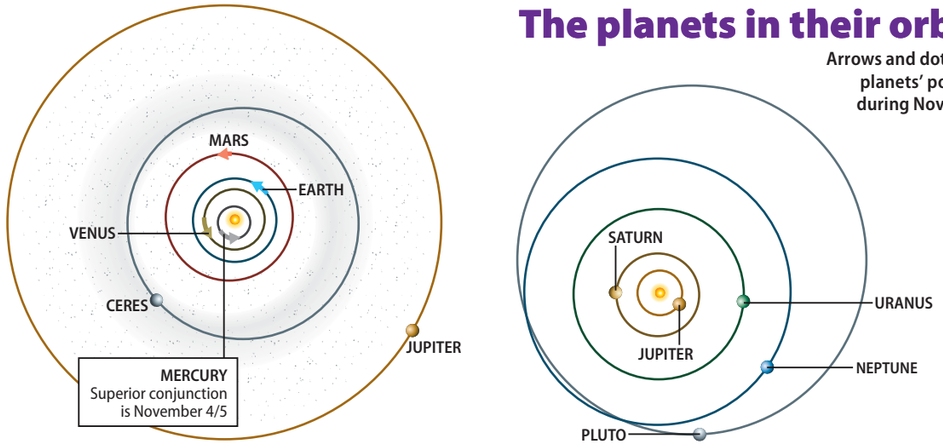
Jupiter's moons

Dots display positions of Galilean satellites at 10 P.M. EST on the date shown.
South is at the top to match the view through a telescope.



The planets in their orbits

Arrows and dots show planets' positions during November.



StarDome

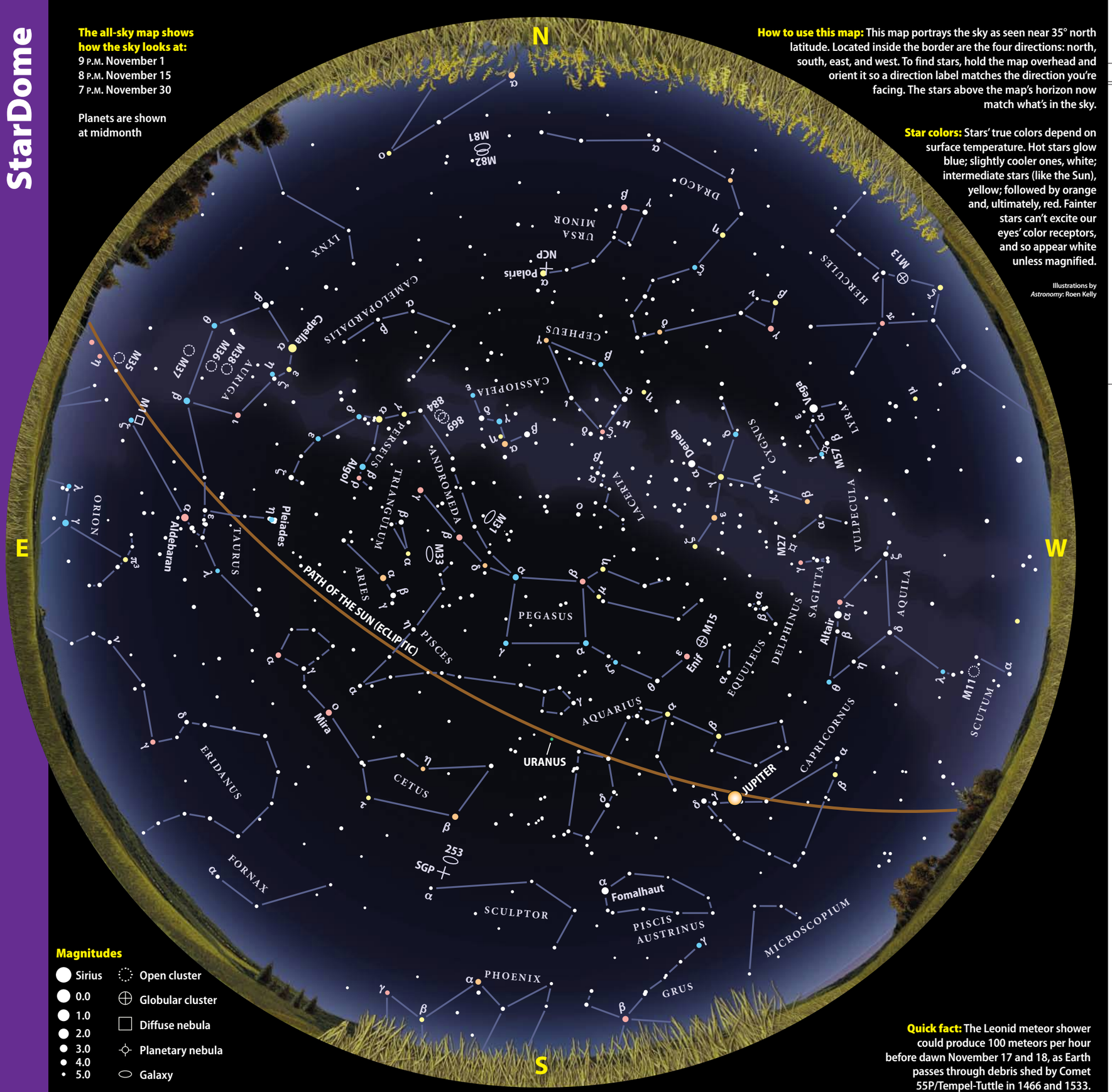
The all-sky map shows how the sky looks at:
9 P.M. November 1
8 P.M. November 15
7 P.M. November 30

Planets are shown at midmonth

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Roen Kelly



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Quick fact: The Leonid meteor shower could produce 100 meteors per hour before dawn November 17 and 18, as Earth passes through debris shed by Comet 55P/Tempel-Tuttle in 1466 and 1533.

November 09

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

Calendar of events

1 Venus passes 4° north of Spica, 9 P.M. EST

Special observing date

1 Mars passes near the center of the Beehive star cluster (M44) before dawn.

2 Full Moon occurs at 2:14 P.M. EST

4 Neptune is stationary, 2 P.M. EST

5 Mercury is in superior conjunction, 3 A.M. EST

7 The Moon is at perigee (229,226 miles from Earth), 2:25 A.M. EST

9 The Moon passes 3° south of Mars, 1 A.M. EST

Last Quarter Moon occurs at 10:56 A.M. EST

12 The Moon passes 8° south of Saturn, 8 P.M. EST

16 New Moon occurs at 2:14 P.M. EST

17 Leonid meteor shower peaks

22 The Moon is at apogee (251,489 miles from Earth), 3:06 P.M. EST

23 The Moon passes 4° north of Jupiter, 5 P.M. EST

24 The Moon passes 3° north of Neptune, 1 A.M. EST

First Quarter Moon occurs at 4:39 P.M. EST

26 The Moon passes 6° north of Uranus, 1 P.M. EST

See tonight's sky in Astronomy.com's STARDOME

Astronomy magazine

— *Continued from page 40*

jovian cloud tops (as happens November 20). And once in a while, all four moons lie east or west of the planet (watch November 11).

The gap between Jupiter and **Neptune** narrows from 6° to 3° during November. Neptune remains east of Jupiter until December 19, when faster-moving Jupiter overtakes it. To find Neptune this month, point your binoculars at the line of three stars north of Delta (δ) Capricorni. The two northern stars, 42 and 44 Cap, form the base of a triangle with Neptune at the vertex.

Neptune glows dimly at magnitude 7.9, roughly 10 times fainter than the pair of nearby stars. A look through a telescope reveals Neptune's 2.3"-diameter disk, which has a subtle blue-gray color. The disk proves this object is a planet and not a star, all of which appear as pinpoints in the eyepiece.

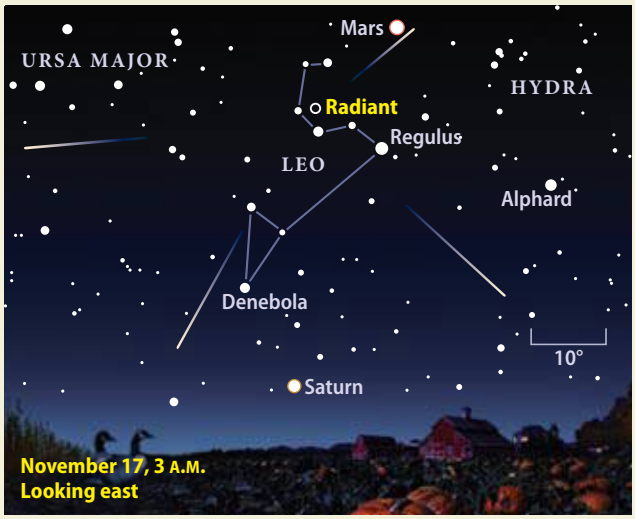
Uranus lies in a sparse region of sky near the border between Pisces and Aquarius. The lack of background clutter will help you identify the 6th-magnitude planet. First, find the Great Square of Pegasus, which stands high in the southeast as darkness falls. Then, lower your gaze to Pisces' Circlet asterism. Neptune lies 6° south-southwest of Lambda (λ) Piscium, the 5th-magnitude star at the Circlet's lower-left corner.

Through 7x50 binoculars, you should see a widely spaced pair of 6th-magnitude stars: 14 and 20 Psc. Uranus lies 2.4° due south of 14 Psc. Turn your telescope on Uranus, and you'll see a disk 3.6" across sporting a distinct blue-green hue. Uranus' colorful disk shows up much more easily than Neptune's does.

Backyard observers have eagerly awaited **Mars**' return to prominence. With opposition and peak visibility now just 2 months away, the wait is over. The Red Planet brightens to magnitude 0.0 in late November. Only Sirius and the Moon shine brighter

Martin Ratcliffe *provides professional planetarium development for Sky-Skan Inc. in Nashua, New Hampshire. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*

Meteor watch



The Leonid meteor shower peaks November 17, when you might see up to 100 meteors per hour under a dark sky. *Astronomy*: Roen Kelly

Leonids could peak big in 2009

November's New Moon coincides with the peak of the annual Leonid meteor shower. If the weather cooperates, viewing conditions should be near perfect. Observers normally can see 20 to 30 meteors per hour at the peak, but rates could spike this year.

Predictions show we should enjoy enhanced rates November 17, most likely between about 1:30 A.M. EST and sunrise. Another rate increase — with numbers reaching 100 meteors per hour for brief periods — may happen later that day, timed well for people across Asia. The higher rates arise because Earth is passing through heavy debris trails left by the Leonids' parent comet, 55P/Tempel-Tuttle.

Although these estimates may make observers salivate, predicting the number of meteors is akin to predicting the number of snowflakes in a storm. We could get lucky and see hundreds of meteors, but we might see only a dozen. One thing is certain: If you're not outside November 17, you'll miss whatever happens.

Rising Moon

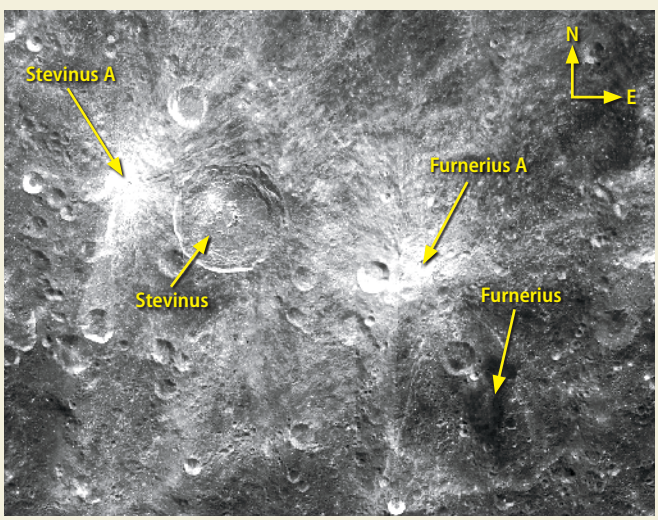
Catch Stevinus and its bright rays

The Full Moon is fascinating, with its wondrous ray systems and ragged limb. To enjoy your eyepiece time, use a filter to cut the glare. (As strange as it may sound, sunglasses will do the trick in a pinch.)

Observers have the opportunity to view a nearly Full Moon at both the beginning and end of November. Take the time to trace bright rays back to their birth craters. Although nothing rivals Tycho's splashy rays, another system is worth your attention. Near the Moon's southeastern limb are the craters Stevinus, Stevinus A, and Furnerius A.

Without a doubt, the two smaller craters (those with the A) are the youngest features here. Bright ejecta blankets and spiky rays surround each. You can see them only from a few days before Full Moon to a day after. Once the Sun begins to set over this region, the lighter and darker albedo features get lost among the hundreds of shadows cast by crater rims and mountain peaks.

Look at the rays that cross Mare Nectaris, the lunar "sea" northwest of this area. Although the most conspicuous one comes from Tycho, a fainter ray cuts across it at a right angle. The latter one seems to trace back to Stevinus A, hinting that this crater might be the source.



A Full Moon treat awaits observers in early and late November when the splashy rays surrounding Stevinus appear brightest. BMDO/NRL/LLNL/LPI/UA

When to view **the planets**

EVENING SKY	MIDNIGHT	MORNING SKY
Mercury (southwest)	Mars (east)	Venus (east)
Jupiter (south)	Uranus (west)	Mars (south)
Uranus (southeast)		Saturn (southeast)

between the time Jupiter sets in the evening and Venus rises before dawn.

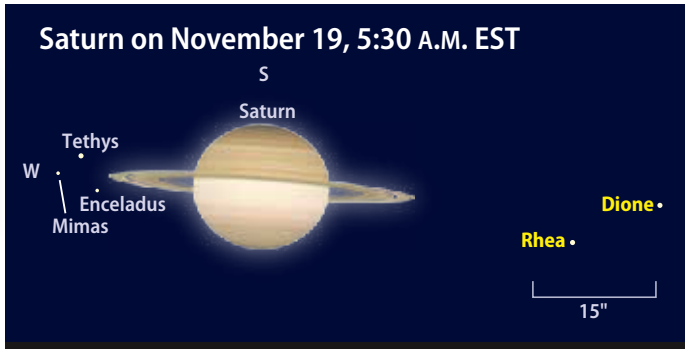
Mars spends November crossing the eastern half of Cancer the Crab. Be sure to turn binoculars on Mars the first two mornings of November. On the 1st, it sits near the center of the Beehive star cluster (M44). By the 2nd, the planet has moved near the cluster's eastern edge. Although Mars rises shortly before midnight, the view improves dramatically a few hours later after the pair climbs higher. By November's close, the planet's eastward motion has carried it to Cancer's border with neighboring Leo the Lion.

Not only does Mars grow brighter during November, but it also grows bigger. The planet's distinctly gibbous disk spans 10" by month's end. At this size, quite a bit of surface detail shows up through an 8-inch or larger telescope. (Still, Mars is barely one-quarter Jupiter's apparent diameter.) The unofficial "Mars observing season" lasts as long as the planet appears 10" across or larger — from late November until mid-March 2010.

The most prominent feature will be the white north polar cap. Mars reached its spring equinox October 26. As the Sun climbs higher in the northern hemisphere sky, the polar cap begins to shrink noticeably. Earthbound observers will have a nice view because this cap now tilts toward us.

Other good features to look for in late November include Mare Acidalium and Solis Lacus, which face Earth in the early morning hours. Syrtis Major, one of the most conspicuous dark features on the martian surface, will be better placed in early December.

Mars takes 24 hours and 37 minutes to rotate on its axis. Those extra 37 minutes above and beyond Earth's rotation mean that if you observe at the same time each night, Mars appears to rotate backward. Or, to put it another way, you need to observe about a half-hour later each night to see the same hemisphere of Mars.



Watch Saturn's moons move before dawn November 19. Dione and Rhea, both of which glow at 10th magnitude, change positions noticeably in as few as 10 minutes. *Astronomy*: Roen Kelly

Mars isn't the only planet to show dramatic improvement this month. **Saturn** rises much earlier and climbs significantly higher into the predawn sky as November progresses. It rises around 3:30 A.M. local time in early November and 2 hours earlier at month's end. By the time twilight begins on the 30th, Saturn stands nearly halfway to the zenith in the southeastern sky.

The ringed planet lies among the background stars of western Virgo. It shines at magnitude 1.1, the same as Virgo's brightest star, Spica. Notice the difference in color between golden Saturn and blue-white Spica. A waning crescent Moon slides past Saturn November 12.

A telescope reveals Saturn's disk, which measures 17" across its equator and 15" through the poles. This fairly small diameter, coupled with the planet's normally subtle atmospheric features, makes the globe look bland.

But the rings are another story. They span 38", and their tilt increases by more than a third during November. (On the 1st, they tilt 3.1° to our line of sight; by the 31st, they widen to 4.3°.) And this comes just 2 months after

Comet search

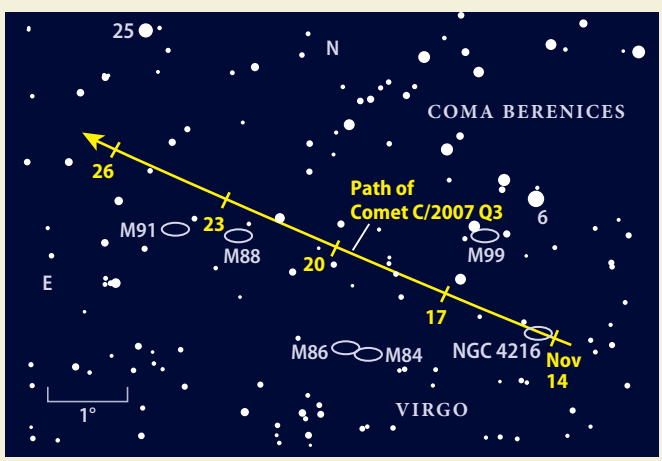
Track a comet through a realm of galaxies

Too often, observers pack up their scopes around midnight and sleep through the glory of the dawn sky. Don't let this happen to you during the New Moon weekend of November 14/15 when a nice comet-galaxy duo awaits. It's a fitting prelude to the conjunction between Venus and the crescent Moon low in morning twilight.

Comet C/2007 Q3 (Siding Spring) passes in front of the Coma-Virgo galaxy cluster for much of this month. Glowing around 10th magnitude, the comet is a bit fainter than the Messier galaxies in the area.

On the morning of November 15, the comet shares a medium-power field of view with the nearly edge-on spiral galaxy NGC 4216. Well-defined and stretching 8' by 2', the galaxy makes a striking contrast with the rounder comet.

If you decide to take a nap until this region climbs reasonably high by 4 A.M. or so, keep your telescope under wraps. The heavy dew that afflicts many places this time of year can cause rivulets of water to run down lenses and mirrors.



Comet C/2007 Q3 (Siding Spring) glows near 10th magnitude as it glides past several bright galaxies in the Virgo-Coma cluster. *Astronomy*: Roen Kelly

Melpomene puts on a whale of a show

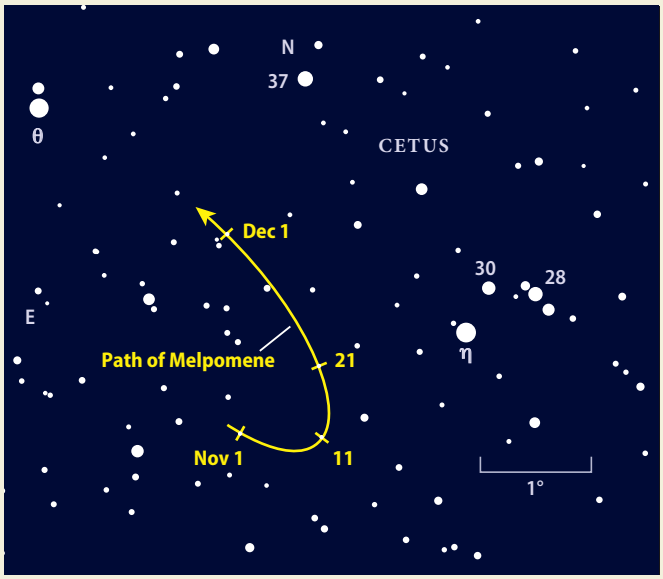
Whether you see Cetus as a sea monster or a whale, it seems appropriate that an asteroid named for the Greek muse of tragedy now lies among the stars of this ravenous beast.

Look for Melpomene during the midevening hours when it lies about a third of the way up in the southeastern sky. Start at the lonely beacon Fomalhaut low in the south. The brightest star to its upper left is 2nd-magnitude Beta (β) Ceti. Slide two binocular fields to Beta's upper left, and you'll arrive at 3rd-magnitude Eta (η) Ceti, our guide for finding Melpomene.

This main-belt asteroid lies about 2° east (to the left) of Eta throughout November. Glowing at magnitude 8.6, Melpomene appears brighter than all but a few of the nearby background stars.

English astronomer John Hind first spotted Melpomene from London in June 1852. It was his fifth asteroid discovery, and the 18th overall. Hind had quite a bit of success searching for asteroids, finding 10 of them during a 7-year period. Melpomene spans 88 miles and rotates on its axis once every 11.6 hours.

We'll have to wait 7 years for Melpomene to glow as bright as it does now. Its elliptical orbit brings it relatively close to the Sun every 3.5 years. At every second return, however, Melpomene lies on the opposite side of the solar system from Earth and appears much fainter.



Melpomene shines at 9th magnitude as it moves slowly through the central regions of Cetus the Whale. You can find it about 2° east of 3rd-magnitude Eta (η) Ceti. *Astronomy*: Roen Kelly

Earth passed through Saturn's ring plane. By the end of the year, the tilt increases to 5°. Late 2009 marks the first time since 1995 that observers can see the rings' northern face.

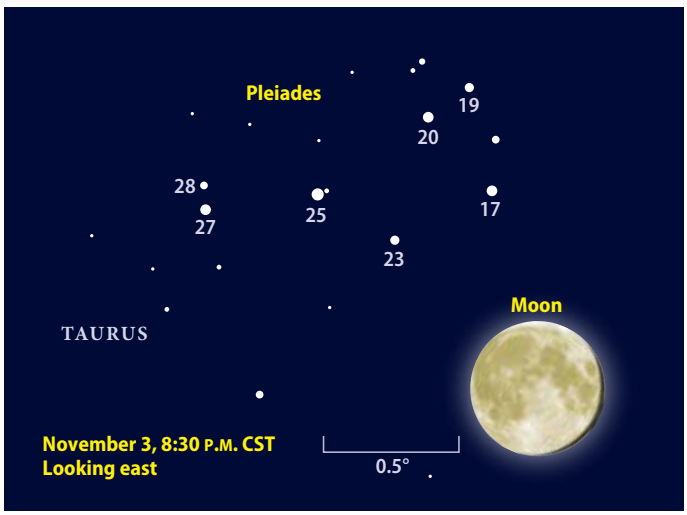
The rings' beauty will draw much of your attention, but don't miss the chance to view Saturn's moons. The brightest, 8th-magnitude Titan, shows up through any telescope. It appears near Saturn November 7, 15, and 23.

You'll need a 6-inch scope to reliably see Saturn's other major moons. The most interesting to earthbound observers is Iapetus, which changes brightness by a factor of five during its 80-day orbit. This moon moves from east to west of the planet during November, passing inferior conjunction before dawn November 11. If you view Saturn that morning, you'll find 11th-magnitude Iapetus near a somewhat brighter 10th-magnitude background star. Iapetus brightens as it moves west of Saturn. Can you notice the change during November?

Saturn's moons present different configurations every night. On November 8, for example, Tethys, Rhea, and Titan line up west of Saturn while Dione lies to the planet's east. The moons don't seem to move much that morning, however. If you like to view motion, mark your calendar for November 19. Dione and Rhea then lie near each other east of the planet, and you can see their relative motion in as few as 10 minutes.

Venus rises 90 minutes before the Sun November 1. It shines brilliantly at magnitude –3.9 and stands 4° north of Virgo's luminary, Spica. The planet now orbits on the far side of the Sun from Earth, so the view through a telescope doesn't impress. Venus shows a 10"-diameter disk that appears 95 percent lit.

The angular separation between the Sun and Venus diminishes during November. By month's end, the planet rises less than an hour before the Sun and will be hard to see in the bright twilight.



A nearly Full Moon slices across the southern part of the Pleiades star cluster November 3. Binoculars or a small telescope afford the best view of this event. *Astronomy*: Roen Kelly

On November 3, a nearly Full Moon rises near the Pleiades star cluster (M45) in Taurus. During the evening hours from North America, you can watch the Moon skirt the cluster's southern regions. The Moon occults a line of 7th-magnitude stars between moonrise and midnight.

For most of North America, the brightest star the Moon covers is Atlas (magnitude 3.6). You can view this occultation through binoculars or a small telescope if you live outside the northwest. Because the time of any occultation varies depending on geographic location, consult the International Occultation Timing Association's web site at lunar-occultations.com. There you'll find a special page dedicated to Pleiades occultations.

How an

The Gemini Observatory captured this image of McNeil's Nebula during the 2004 flare-up of the star V1647 Orionis, a month after amateur Jay McNeil discovered the nebula. Radiation from the flaring star cast reflections within a cone-shaped cavity north of the star. Gemini Observatory

While imaging the reflection nebula M78 (main image), amateur astronomer Jay McNeil inadvertently discovered a smaller gas cloud that now bears his name. Astroimager Tony Hallas created this portrait in November 2008.

amateur astronomer changed stellar astrophysics

Thanks to Jay McNeil's discovery, we may soon know what feeds X-ray outbursts from young stars. **by Adam Frank**

It's one of those problems that won't go away. Young suns shine brightly in X-rays, and no one is quite sure why. After decades of lofting satellites above the atmosphere to catch astronomical X-rays, researchers knew star formation and X-rays go together in a big way. How and why they go together and what the X-rays can tell us about assembling a star, however, were still unclear.

Then, one night in January 2004, an amateur astronomer named Jay McNeil trained his 3-inch refractor on an obscure region of Orion. What he saw there set the wheels of discovery in motion and turned the debate about star formation and X-rays on its head. A fire blazed in the nebula McNeil found, and for once astronomers were there to see it burn.

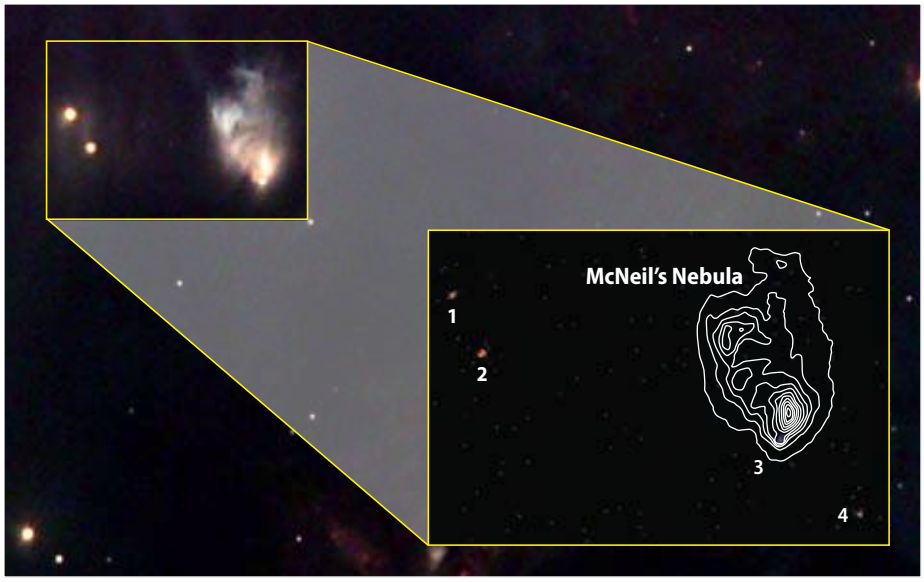
Lucky break

It was a cold and windy (but, fortunately, clear) night in Paducah, Kentucky, when Jay McNeil made the 30-foot trek to his backyard observatory. A satellite disk installer by trade, he is a sophisticated amateur astronomer who routinely carries out imaging programs in various parts of the sky. "I was trying out a new small telescope," McNeil told National Public Radio 6 months later. "Since it was so cold, I quickly took some images in the region of Orion and went back inside. I didn't get back to processing the images for a few days."

When he returned to his images 3 days later, he noticed something within the reflection nebula M78. "At first I thought it was just some kind of odd reflection on one of my frames," he said, "but after processing the whole image I saw the object was something very peculiar and very real."

McNeil then jumped online to check his discovery against available data. He was looking for positions of objects in that part of Orion and

McNeil's Nebula brightens gradually in a series of images taken at the Llano del Hato National Astronomical Observatory in the Venezuelan Andes from October 25, 2003, to January 27, 2004. Light and X-rays from a flaring young star, V1647 Orionis, illuminates the nebula's gas and dust.



The Chandra X-ray Observatory detected the point-like X-ray sources numbered 1 to 4 in this image. Source number 3 (inset) recorded the signature of V1647 Ori, the star illuminating McNeil's Nebula. The Very Large Telescope in Chile took a 10-second exposure to record the rough contours of McNeil's Nebula. Main image: NSF/NOAO/KPNO/A. Block et al.; X-ray sources: NASA/CXC/RIT/J. Kastner et al.; nebula contours: ESO/VLT

found none. A week later he sent off an International Astronomical Union (IAU) telegram announcing the discovery.

"You gotta take a look at this!" said Michael Richmond as he burst into Joel Kastner's office. Richmond and Kastner are astronomers at the Rochester Institute of Technology in New York. Richmond had come across McNeil's discovery from images posted on the Web by other observers. He knew it was the kind of thing that would spark the interest of a star-formation expert like his colleague. Kastner did not disappoint him.

Adam Frank *is a professor of astrophysics at the University of Rochester in New York. His most recent article for* Astronomy, *"How to make a solar system," appeared in February 2009.*

A nebula is born

After the IAU posted Jay McNeil's telegram, professional astronomers turned their bigger telescopes to the same region of the sky. There they found a bright cone of gas and dust illuminated by a young sun at the cone's apex.

Dubbed "McNeil's Nebula," the region became visible when light from the newly forming star bounced off gas and dust along the walls of an evacuated cavity, creating the conelike nebula.

Astronomers quickly realized that the bright reflection nebula had not existed a few years earlier. They had imaged the star at the base of the nebula, V1647 Orionis, but it glowed faintly. Now the star had suddenly flared to 50 times its former brightness in just a few months.

For Richmond and Kastner, it was a potential goldmine. They knew such flaring was thought to be a critical phase in the evolution of a natal star. They also knew the flaring is rare.

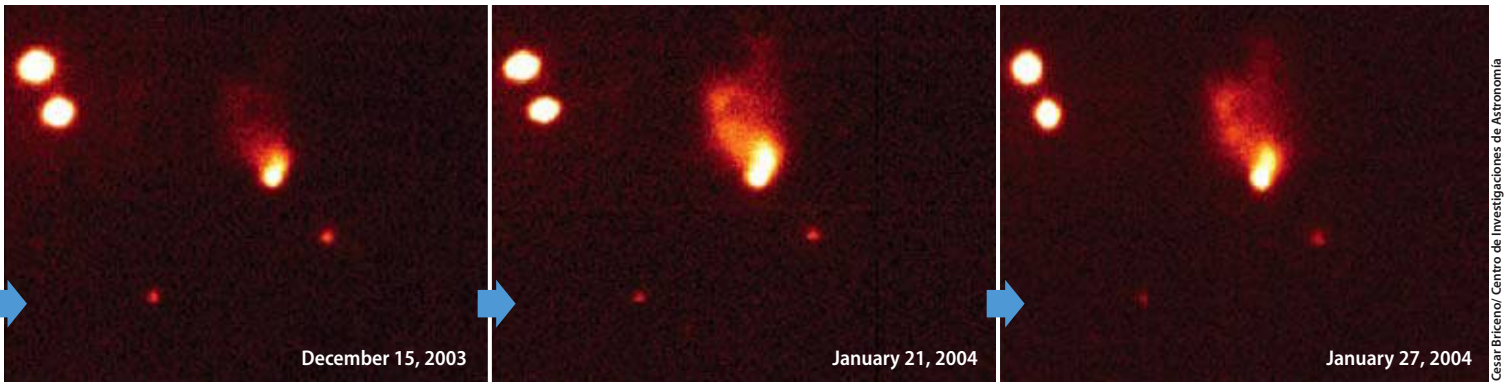
Scientists have caught only a few stars in the act of flaring, and each case occurred before the advent of modern telescopes and space-based observatories. For Kastner, an expert in X-ray emissions from young stars, V1647 Orionis' flare-up represented the chance of a lifetime. Theorists had a basic idea of why young stars flare, but the details remained controversial. Could McNeil's Nebula solve this mystery?

Building a new star

Stars are born through a process called accretion. The recipe for assembling stars begins with vast clouds of gas and dust threaded by magnetic fields. Every so often, a portion of the cloud, called a core, will collapse on itself. Material in the cloud core rains toward the center, and the seed of a new star forms.

The star core always begins with some rotation because of the parent cloud's mix of turbulent rolling and roiling motions. Like a twirling skater pulling her arms inward, gas in the core rotates faster as it contracts. Eventually the gas forms an orbiting disk around the protostar.

This disk becomes the mediator of the young star's growth: To reach the star, gas must first pass through the "accretion disk" and then drop onto the star. Astronomers have studied the properties of these gaseous Frisbees, trying to understand what makes them tick. The disks also spawn new planets, which means they are doubly important.



Cesar Briceno/ Centro de Investigaciones de Astronomia

Traffic flow

One thing nobody understands is what regulates the flow of matter through an accretion disk. Is the flow steady, feeding the star with a constant supply of gas? Or is it irregular, with big burps of matter dumped onto the young star all at once?

Astronomers suspect that magnetic fields also affect accretion in dramatic ways. For example, the field from the young star can be so powerful that it pushes the disk away.

That motion creates a gap between the star and the inner disk edge. Hot, electrically charged (ionized) disk material then has to ride magnetic field lines to jump the gap and reach the star.

Researchers have developed a category of mathematical models to understand the way magnetic fields control the flow of material between accretion disks and stars. Both the steadiness of accretion through the disk and the role of magnetic fields in accretion are significant issues in the study of star formation. What astronomers lacked were observations showing how accretion proceeded in a real disk.

NASA/CXC/Penn State/E. Feigelson & K. Getman et al.

The Orion Nebula (M42) harbors a loose association of about 2,000 mostly young suns. As the Chandra X-ray Observatory imaged the cluster continuously for 13 days, many of the stars emitted strong X-ray flares. Such flaring seems to be an intrinsic stage of stellar evolution.

Astronomers got some early clues in 1937 when the star FU Orionis emerged from relative obscurity at 16th magnitude and brightened by a factor of 100 in 200 days. It became clear that FU Ori represents a class of stars that suddenly increase their brightness and then take decades to return to their original output.

Subsequently, researchers came to suspect every FU Ori event was due to a rapid increase in mass flow through an accretion disk. When mass falls on the star, it releases its gravitational energy in the form of light.

Importantly, FU Ori events showed that disk accretion could be unsteady. Some scientists conjectured that repeated FU Ori "events" could represent a critical phase in the assembly of a sun. The problem was that astronomers had observed only a handful of FU Ori type stars — and usually after the outbursts had begun, when their power output was already in decline. The last time researchers had caught a full-fledged FU Ori event in the act was in the 1970s, although astronomers had cataloged many cases of shorter-duration or smaller FU-Ori-like eruptions since then.

It was a potential goldmine. They knew such flaring was thought to be a critical phase in the evolution of a natal star. They also knew the flaring is rare.

X-ray eyes

There have been many advances in observing technology since then. Indeed, Kastner built a chunk of his career using one of those great advances: the Chandra X-ray Observatory. So when Richmond burst into his office with news of McNeil's Nebula, Kastner immediately thought of Chandra.

Kastner had been studying X-rays from young stars for the previous decade or so and knew the debate about their origin quite well. The argument hinged on understanding not just X-rays but the magnetic fields that appeared everywhere in star-formation studies.

"Magnetic fields and X-rays have always been linked in astronomy," says Kastner. When researchers first began lofting X-ray cameras high enough above the atmosphere, the first thing they saw was the Sun and its magnetic corona.

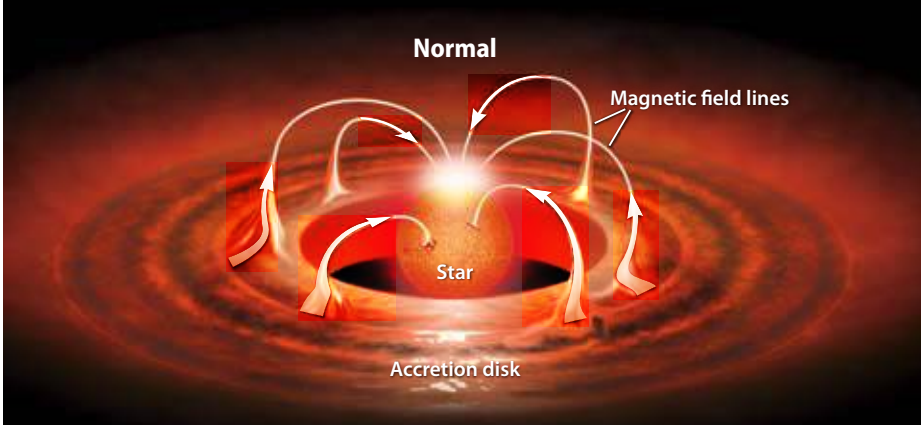
The Sun has a powerful magnetic field, and giant eruptions of magnetized gas called solar flares produce bursts of X-rays. "When we look at young stars with telescopes like Chandra, we also see bright X-rays," Kastner explains. "The link with the Sun was so convincing for most astronomers that there is a general belief that young stars also produce their X-rays in coronal flares."

Because young stars should be rotating faster than the Sun and therefore should have more powerful magnetic fields, it made sense to many astronomers that they would also appear as brighter X-ray sources.

Kastner never completely bought into this explanation. Over the years, he came

What feeds flaring in young stars?

Astronomers have seen many young stars periodically unleash outbursts of visible light and infrared radiation lasting months or even years. But what powers the flare-ups remains unclear. In the most widely accepted scenario, flares result from a huge increase in the rate of infall of matter from a protoplanetary disk of dust and gas onto the star.



During normal periods, hot, electrically charged gas from the disk's inner edge migrates along the star's magnetic field. The gas falls onto the star, generating a relatively steady glow of ultraviolet radiation, visible light, and perhaps X-rays.

During a flare-up, the inner edge of the disk closes in tighter on the star, disrupting the formerly orderly magnetic connections between the star and the disk. Large amounts of material flow onto the star's surface, feeding a dramatic increase in light output across a broad range of the electromagnetic spectrum, from infrared to X-rays. *Astronomy:* Roen Kelly

to see the link between X-rays and young stars differently. "We know accretion through disks occurs, and we also know that the disks can be pushed away by the stellar magnetic fields," he says.

This implied that stellar magnetic fields somehow regulate accretion. "It always made sense to me that X-rays from young stars should be linked to accretion and not just to stars and their coronae," Kastner says. The magnetic fields regulate flow through the accretion disk and onto the star's surface, where mass falling on the star produces X-rays.

With this picture in his head, the news took Kastner to the central question: "If the star at the center of McNeil's Nebula is brightening in the visible because of accretion, then is it also brightening in X-rays, too?" Kastner knew that if the star did emit X-rays, it could be the smoking gun that would prove the link between accretion and X-ray production. The only way to find out would be to get some time on Chandra, and get it fast.

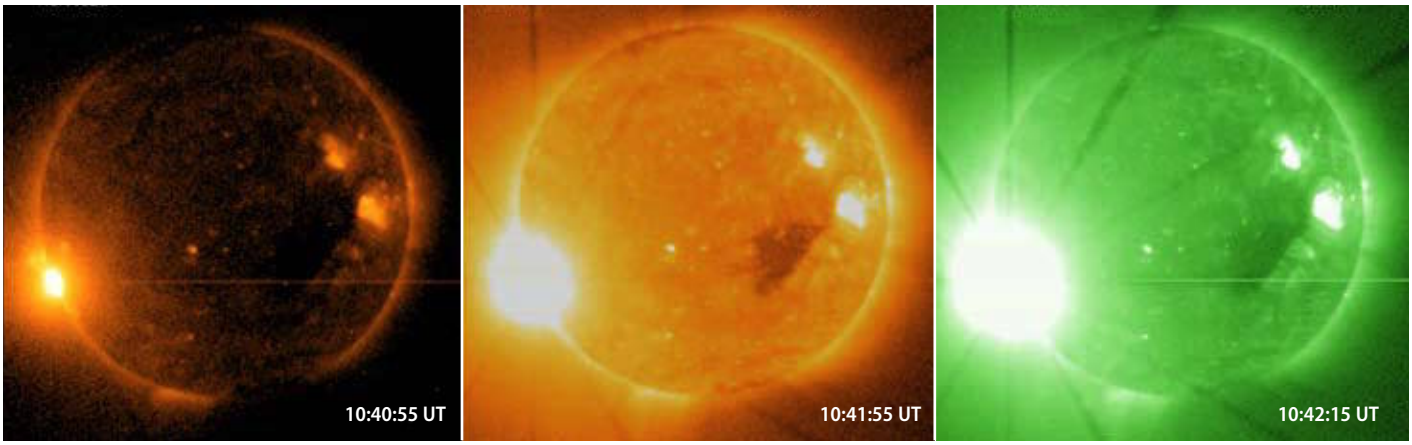
X-ray eyes

Kastner, Richmond, and their collaborator David Weintraub from Vanderbilt University could not wait the months it would take to get a conventional proposal approved for time on Chandra. They needed to catch the star powering McNeil's Nebula while it was still flaring. Fortunately, they were able to garner time set aside for unforeseen opportunities like the outburst of V1647 Ori.

Just before Chandra acquired its observations, Kastner received an e-mail from Nicolas Grosso at the Laboratoire d'Astrophysique in Grenoble, France. Grosso had just gotten observing time to look at McNeil's Nebula with the European X-ray satellite XMM-Newton. Both Chandra and XMM had their strengths. While Chandra had better spatial resolution, XMM could provide a superior look at X-ray spectra.

Kastner and Grosso decided to combine forces and form a small team that would coordinate X-ray observations and their interpretation. When Kastner and the team got a good look at the data, they saw that the star had flared in X-rays just like it had in all the other wavelengths.

"The star went from barely detectable in X-rays to being the second-brightest



Even our middle-aged Sun can produce wickedly powerful X-ray flares, albeit by a different mechanism than the star that made McNeil's Nebula light up. The GOES-13 satellite's X-ray Imager sustained damage to one of its detectors while observing this powerful X-ray flare December 5, 2006. NOAA

object in that region," explains Kastner. "We saw a 50-fold increase in brightness."

Soon the team had the XMM data in hand, as well. When they plotted the X-ray light curves, which measure brightness over time, the X-rays marched in lock step with all the other forms of light. Kastner was looking right down the barrel of his smoking gun. It looked like X-rays and accretion did go together.

Vindication

After years of arguing for the minority position that disk accretion leads to protostellar X-rays, Kastner was feeling justifiably vindicated. "At first I thought this is all the proof we need — there is no more to say," Kastner recounts. "Then I realized that was kind of naive."

Science is a conservative business. Evidence pointed to coronal magnetic activity as the source of the X-rays in young stars, and Kastner's collaborators did not want to make unsupportable claims. "They weren't quite ready to jump on that bandwagon," Kastner says.

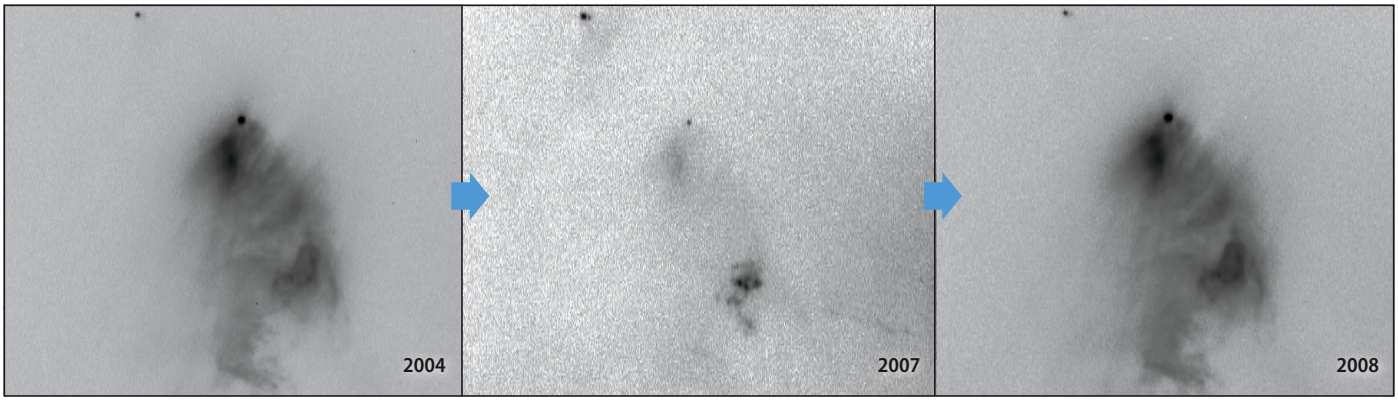
What followed was a prolonged give-and-take, via e-mails, as the team wrote an article for the prestigious journal *Nature*. Kastner's team made sure it was not overstepping what the data could support. "It took some work to convince everyone in the group," Kastner says. "In the end we said the results showed accretion could enhance X-rays. We didn't claim it was the sole source." The article went to *Nature*, cautious language and all, and the journal published it.

The key for theoretical astrophysicists now is to understand exactly what generates the X-rays when a big surge in disk accretion occurs. The most likely scenario involves magnetic fields that push the disk away from the stellar surface. If a lot of matter rushes toward the star, then the fields can't force the disk to keep its distance. As the disk edge pushes inward, the fields reorient themselves and release their energy in magnetic flares, which then create high-energy radiation.

McNeil's Nebula and V1647 Orionis did not end the debate over X-rays in young stars, but they did have an impact. "Some people will say that it's just the exception which proves the rule," Kastner says. "Others are willing to recognize that accretion has to play some role even though many or even most young stars probably do generate their X-rays just through coronal activity."

The argument will continue, but nature has shown itself just a little more clearly. Whatever the final outcome, V1647 Orionis' little temper tantrum allowed both Jay McNeil and Joel Kastner to participate in that rarest of scientific events — the discovery of something new, unexpected, and wonderful.

Take an animated tour of the sky region near McNeil's Nebula at www.Astronomy.com/toc.



V1647 Orionis may be in the midst of a continuing outburst that wavers in its intensity, some astronomers believe. After its chance discovery in 2004, McNeil's Nebula faded for several years and then had a repeat outburst in 2008. Astronomers once again began tracking its X-ray emissions with the Chandra X-ray Observatory and the European XMM-Newton satellite. Colin Aspin (Institute for Astronomy, University of Hawaii)

Ask Astro

Astronomy's *experts from around the globe answer your cosmic questions.*

M33's ultimate fate after the merger

Q: Will the galaxy M33 be involved in the merger between our Milky Way Galaxy and the Andromeda Galaxy?

— Michael Amato, West Haven, Connecticut

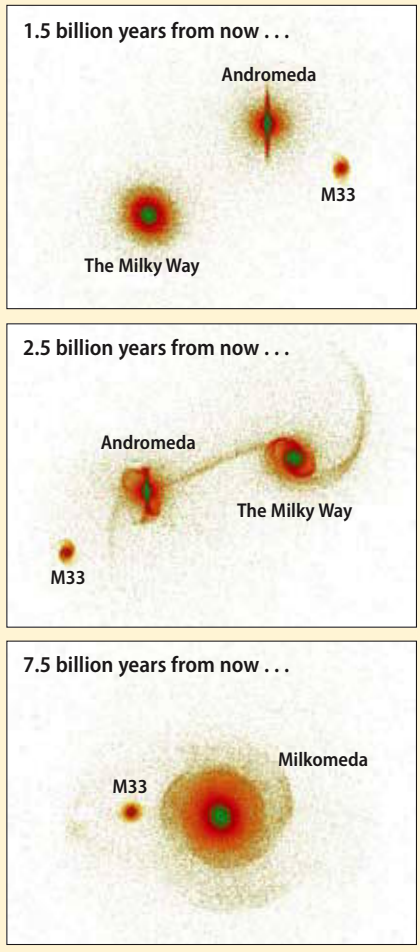
A: During the next 5 billion years, the Milky Way Galaxy and the Andromeda Galaxy (M31) will merge to form a new galaxy — Milkomeda. **The Triangulum Galaxy (M33), a satellite to Andromeda, will be swept up in the merger and probably assume a new path through our Local Group of galaxies.**

Mutual gravitational attraction binds Andromeda and M33. As a result, M33 will likely be carried along during the merger of the Milky Way and Andromeda.

Owing to the Triangulum Galaxy's smaller mass — less than one-tenth of Andromeda's — its involvement in the merger will be one of an innocent bystander. Its comparatively small gravitational tug won't affect any of the overall merger dynamics between the Milky Way and Andromeda.

However, the encounter will create gravitational tides that will cause M33's path to become wildly variable. A simple analogy might be a piece of furniture on the back of a truck that gets into an accident. The fact that the furniture is there didn't influence the accident, but the furniture probably went flying off in some direction because of it.

In the end, the Triangulum Galaxy may remain a satellite galaxy, but of the new merged galaxy, Milkomeda, instead of Andromeda. The wild ride it experiences will certainly warp its physical structure to some extent. Eventually, M33's orbit will decay, and Milkomeda will gobble it up. **— Thomas J. Cox,** Harvard-Smithsonian Center for Astrophysics, Cambridge, Massachusetts



A computer simulation of the Milkomeda merger shows that the Triangulum Galaxy (M33) remains intact throughout the process.

EXISTENTIAL ASTROPHYSICS

Q: Is it possible for a large star to collapse itself out of existence rather than just forming a black hole? — Martin Andrzejewski, Mustang, Oklahoma

A: Black holes form in the collapse of massive stars. They consist of matter in some incredibly dense state, with gravity so powerful that not even light can escape its grip. But the ultimate victory of gravity is the formation of a black hole. It represents the most extreme collapse of matter possible.

An object "collapsing out of existence" implies a violation of the principle of conservation of mass-energy, which is one of the most cherished principles of physics. It says that the total amount of mass and energy in the universe must remain constant. Mass or energy can change form or location, but it always continues to be part of the universe. **Therefore no, a large star could not collapse itself out of existence.**

For example, as a star collapses, a portion of its mass is converted into energy. This is clearly the case during a supernova explosion or gamma-ray burst following a star's collapse. The energy liberated during these events is what makes them visible. The mass does not disappear — it just changes form and radiates outward from the blast.

Even in the extreme case in which a massive star is completely blown apart at the end of its life, the mass and energy do not disappear. They are carried away in the stellar debris left after the explosion.

Scientists have investigated the possibility that a black hole could create a "tear" in space-time, often called a wormhole, leading to some other location in the cosmos. But even if wormholes existed, whatever entered one through a black hole would not disappear forever. It would simply pop up somewhere else in the universe. **— Eliot Quataert,** Theoretical Astrophysics Center, University of California, Berkeley

To find out what would happen if Earth lost its protective ozone layer, go to www.Astronomy.com/toc.

ASTEROID WATCH

Q: Will the MESSENGER probe to Mercury be able to get a photograph of the asteroid Icarus? — John Lockwood, Washington, D.C.

A: No. The asteroid 1566 Icarus has an orbit that carries the rocky body closer to the Sun than Mercury. The ideal time for the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft to attempt an observation of Icarus would be in January 2012, after the spacecraft is already in orbit around Mercury.

Icarus would then be about 11 million miles away from MESSENGER (17.4 million kilometers), or approximately 45 times the distance from Earth to the Moon. But even at that time, **Icarus will be way too faint for MESSENGER's instruments to observe it.**

In mid-June 2015, Icarus will come within about 5 million miles (8 million km) from Earth, or about 20 times the distance to the Moon. At that time, Icarus will be about as bright to us on Earth as it would be to MESSENGER under the best viewing conditions possible. On the astronomical brightness scale, the asteroid will shine with the same intensity as a magnitude 13 star, which is about the same brightness as Pluto seen from Earth.

Astronomers will still be able to observe Icarus despite its extreme dimness. Ground-based telescopes are much larger and more powerful than MESSENGER's instruments because they don't have to be miniaturized to fit on a spacecraft. **— William Merline,** Southwest Research Institute, Boulder, Colorado

TELESCOPE BASICS

Q: I have a 70-millimeter refracting telescope. Would a scope with a larger diameter make objects look bigger or closer? — Mike Haverko, Kelowna, British Columbia

A: All other factors being the same, increasing diameter ("aperture") means your image will be brighter and more detailed, but not necessarily larger. So, if you use the same eyepiece to observe Jupiter with a 2-inch, 6-inch, or 12-inch telescope — and if all three scopes have the same focal length — Jupiter will be the same size. That said, larger scopes of the same design usually have longer focal lengths, so they would make a celestial object appear larger.

Figuring out how much an eyepiece magnifies is easy. Just divide the scope's focal length by the eyepiece's focal length. You'll find that number on the eyepiece followed by "mm." So, if you put a 10mm eyepiece into an 8-inch scope that has a focal length of 1,000mm, the magnification is 100x (1,000 divided by 10). A 4-inch scope with the same focal length and eyepiece would produce the same result (100x), but the object would not be as bright because the smaller aperture collects less light.

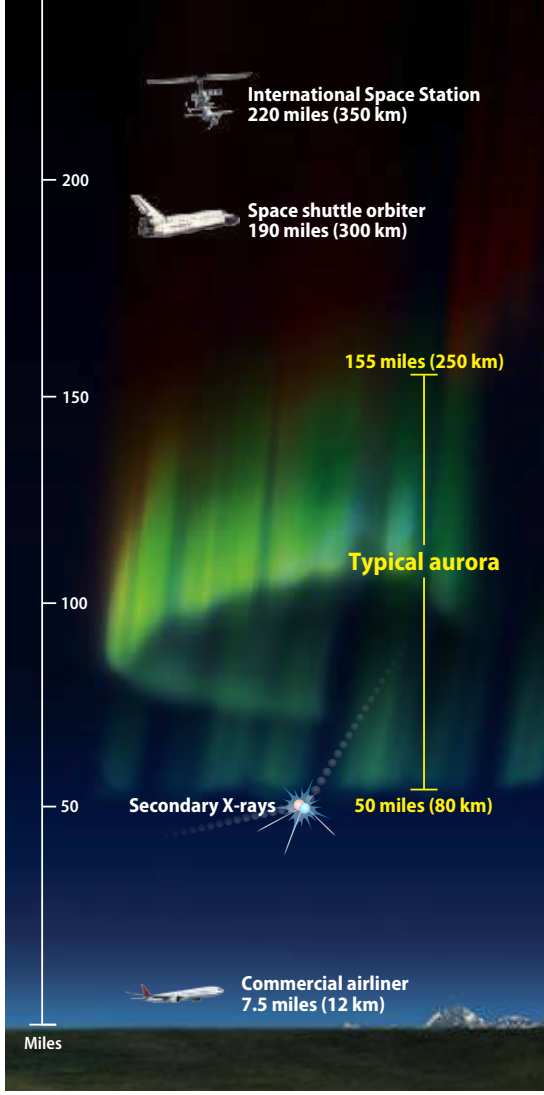
To make celestial objects look larger through your telescope, use eyepieces that provide higher magnification. A 10mm eyepiece provides twice the magnification of a 20mm eyepiece in the same telescope. Likewise, a 5mm eyepiece would double the magnification of a 10mm. **— Michael E. Bakich,** Senior Editor

SPACE WEATHER

Q: Does flying in a plane underneath the aurora expose a person to radiation? Would it be dangerous? — Menachem Goren, Petach Tikva, Israel

A: Auroral displays occur as charged particles from space follow Earth's magnetic field into the atmosphere at high latitudes. The auroral particles include both electrons and protons. These particles originate in the magnetosphere but get their energy from the "solar wind" of particles streaming from the Sun. **Particles streaming into Earth's atmosphere during times of intense solar activity could expose airline passengers to slightly higher radiation, but the dose is so small and infrequent that it does not represent a significant hazard.**

As the particles collide with gas molecules in Earth's atmosphere, they create the auroral light. The farthest auroral particles penetrate the atmosphere is to an altitude of about 50 miles (80 kilometers). The highest airliners normally fly is about 40,000 feet, or 7.5 miles (12 km). This altitude is far below the reach of the most energetic auroral particles.



The charged particles from space that generate the aurora never come closer than about 50 miles (80 kilometers) above Earth's surface.
Astronomy: Roen Kelly

As auroral particles collide with gases in the atmosphere, some trigger a cascade of secondary X-rays. These X-rays penetrate another 6 to 9 miles (10 to 15 km) deeper into the atmosphere. This is still too high to reach an airliner.

During intense solar storms, Earth's magnetic field provides weaker shielding from the space environment and a larger number of particles called solar protons may reach airliner altitudes. The occasional exposure that airline passengers experience is small and likely poses no health risk. **— Dirk Lummerzheim,** Geophysical Institute, University of Alaska, Fairbanks

Send your questions via e-mail to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI, 53187.** Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

Watch as galaxies collide

Even at vast distances, galaxies twist and distort each other into weird shapes. Target these 10 fascinating extragalactic train wrecks. **by Alan Goldstein**

The night sky is riddled with galaxies — vast agglomerations of stars, dust, and gas. The sizes of galaxies vary from several million stars stretching a couple thousand light-years to more than a trillion stars spanning several hundred thousand light-years. A lot of empty space lies between galaxies, but this is deceiving. Galaxies even millions of light-years apart may have some mutual gravitational attraction drawing them together. The effect both builds and destroys galaxies. These galaxy collisions can be spectacular, hurling stars millions of light-years into intergalactic space.

Astronomers believe the galaxies you can see in your telescope result from the collision and absorption of others. Physical laws favor the bigger galaxies when they smash together. Like a freight train hitting a compact car (where the pieces scatter from the impact), the result from a galactic collision can be a celestial object of amazing complexity.

Mergers between galaxies can make for breathtaking photography and interesting visual observations. Watching galaxies collide is akin to seeing nature's finest drama within a single still-frame image. It would take thousands of lifetimes to see any changes between interacting galaxies. Disappointed? Don't be. Plenty of action is out there, and your telescope will let you observe almost every possible type of interaction.

A celestial odd couple lies in the constellation Draco. The lenticular galaxy NGC 5965 (top center) attracts the spiral galaxy NGC 5963 (lower right). Ken Crawford

The Andromeda Galaxy (M31) is the nearest spiral galaxy to the Milky Way. M31 imposes a gravitational tug-of-war upon its smaller dwarf satellite, M32 (left of center). Thomas V. Davis

Near misses — or near hits

The gravitational attraction between passing galaxies can be powerful even when they don't appear to be in direct contact. Studies show that most galaxies are surrounded by a halo of gas and invisible dark matter that adds to their bulk. As a result, even a near miss can alter the shape of one or both galaxies.

The **Andromeda Galaxy** (M31) and its dwarf companion **M32** are the easiest pair of interacting galaxies to observe. M32's proximity doesn't affect the large spiral much, but, in time, the small galaxy will suffer. The bright, compact elliptical is visible within the overall glow of the disk of M31. It is a good target for telescopes of any aperture.

NGC 2207 and **IC 2163** form a pair of spiral galaxies in Canis Major passing by each other. The result is a dramatic image, one of the favorites from the Hub-

Astronomy *contributing writer* **Alan Goldstein** *has observed the night sky since 1973.*

The Antennae (NGC 4038 and NGC 4039) in Corvus the Crow were once separate spiral galaxies. A violent clash between the two more than 500 million years ago created a new beast sporting tails of stars, gas, and dust resembling an insect's antennae. Daniel Verschatse/Antilhue Observatory

ble Space Telescope. Visually, NGC 2207 appears evenly illuminated and somewhat oval, while IC 2163 is an open spiral with a low surface brightness that gives it a ghostly appearance in comparison. Both are bright and relatively easy to see in a modest scope under good skies. Larger scopes should reveal a compact nucleus in IC 2163.

NGC 4618 is a barred spiral interacting with **NGC 4625** in Canes Venatici. The latter appears to be a compact spiral, but in reality it has a large disk with low surface brightness. So although NGC 4625 appears to be the smaller of the pair, it is actually physically larger!

In his 1966 publication on peculiar galaxies, Halton C. Arp noted this duo as odd because the interaction created a pair of one-armed spirals. The interaction has triggered intense star formation in both members. You can see these galaxies with an 8-inch scope; NGC 4618 dominates the scene.

The widely spaced interacting system of **NGC 5963** and **NGC 5965** consists of a spiral and a lenticular galaxy. Astronomers originally categorized the latter as

Thalia and Norman Terrell/Adam Block/NOAO/AURA/NSF

In 1835, English astronomer John Herschel discovered the colliding spiral galaxies NGC 2207 and IC 2163. The pair lies some 144 million light-years away in the constellation Canis Major.

an elliptical galaxy with unusual gas and dust clouds. The two galaxies lie in Virgo and have 14' of declination between them. NGC 5965 appears relatively unfazed by NGC 5963's proximity. Both are good targets for small telescopes. NGC 5965 has an oval glow, while the spiral appears smaller because of the arms' low surface brightness, which require a large scope to see clearly.

Fly-by-night

Another class contains interacting galaxies that are in contact but do not appear to be head-on collisions. I call these "fly-by-night galaxies" because they graze each other — their outer edges interacting — but the main bodies remain intact. (The smaller galaxy of the pair usually appears much the worse for wear.) Eventually the two objects will merge, but at the moment both appear largely intact.

NGC 3226 and **NGC 3227** are fly-by-night galaxies, easy to locate 1° east of Gamma (γ) Leonis in Leo. At magnitudes 11.4 and 10.3, respectively, this pair consists of an elliptical and a spiral galaxy. Their proximity has not distorted either

The Whirlpool Galaxy (M51) is a large "grand design" spiral interacting gravitationally with a smaller spiral companion, NGC 5195 (left). M51 is one of the most popular and recognizable targets for Northern Hemisphere observers and imagers. Keith B. Quattrocchi

Chris Schur

Gravitational grappling between NGC 4485 (top) and its companion, NGC 4490, has set both alight with new star formation. Such starburst activity is common to interacting galaxies.

Sid Leach/WI Milan/Adam Block/NOAO/AURA/NSF

The dwarf elliptical galaxy NGC 3226 (lower right) is smaller and fainter than its spiral companion, NGC 3227. The latter's bright central nucleus harbors a supermassive black hole.

10 galactic train wrecks

Name	R.A.	Dec.	Mag.	Size
M31/M32	0h43m	41°16'	3.4/8.1	185' by 75'/11' by 7.3'
NGC 2207/IC 2163	6h16m	–21°22'	10.8/10.9	4.8' by 2.3'/3' by 1.2'
NGC 3226–7	10h24m	19°52'	11.4/10.3	2.5' by 2.4'/6.9' by 5.4'
NGC 4038–9	12h02m	–18°53'	10.5/10.3	5.4' by 3.9'/5.4' by 2.5'
NGC 4618/25	12h41m	41°09'	10.8/12.3	4.1' by 3.2'/ 1.4' by 1.3'
NGC 4485/90	12h31m	41°38'	9.8/11.9	6.4' by 3.3'/2.7' by 2.3'
NGC 4676	12h46m	30°44'	13.0/13.2	2 by 0.3 / 1.7' by 0.7'
M51 (NGC 5194–5)	13h30m	47°12'	8.4/9.6	8.2' by 7'/ 6.4' by 4.6'
NGC 5128	13h26m	–43°01'	6.7	31' by 23'
NGC 5363–4	13h56m	5°15'	10.1/10.5	5' by 3.2' / 6.6' by 5.1'

R.A.=Right ascension (2000.0); Dec.=Declination (2000.0); Mag.=Apparent magnitude.

appreciably, although deep photos show an effect on their extended stellar halos.

You should notice a bright stellar nucleus within NGC 3227. At its explosive core lies a supermassive black hole. This pair is an easy target through a 6-inch telescope and looks even more impressive through larger scopes.

Canes Venatici is a small constellation endowed with multiple interacting galaxies. The **Whirlpool Galaxy** (M51) is not only a favorite of the spring sky, but it's also among the leading deep-sky targets for observers in the Northern Hemisphere. Called the Whirlpool Galaxy because of its easy-to-see spiral arms, M51 rates as the most famous interacting galaxy pair in the sky.

This object consists of **NGC 5194** and its dusty, peculiar companion, **NGC 5195**, which glow at magnitudes 8.4 and 9.6, respectively. Visible through binoculars, a 4-inch optical system will show this pair well. A moderately sized scope reveals its sweeping spiral structure. Through apertures of 12 inches or higher, some of the detail captured in astronomical images becomes apparent.

If not overshadowed by the Whirlpool, **NGC 4485** and **NGC 4490** could be the best-known colliding pair in Canes Venatici. These Magellanic-type galaxies show slight hints of spiral structure in images. The larger member, NGC 4490 (recently named the "Cocoon Galaxy"), has a condensed nuclear region.

Like NGC 4618 and NGC 4625 (discussed previously), NGC 4485 and NGC 4490 also show dramatic star-forming regions — except in this case on the facing sides of each galaxy. Both are bright targets for a small telescope and are among the easiest interacting galaxies to find. They lie less than 1° northwest of Beta (β) Canum Venaticorum.

Impact!

When galaxies hit hard, the result can be a real mess. Spiral galaxies may become so distorted and tangled that two become one. A number of interacting galaxies do seem, at first glance, like single, weird galaxies. However, the Hubble Space Telescope has sufficient resolution to bring the murky messes into sharp focus.

The **Antennae Galaxies** — NGC 4038 and NGC 4039 — are a pair of spiral galaxies in "full contact." The "antennae" idea comes from the fact that the interaction has flung stars in a pair of slightly curved arcs — called tidal tails — many times the diameter of both galaxies into deep space. The collision has energized star-forming nebulae on the facing sides and thrown dust arcing between them. The unusual shape is easily detectable in a small telescope. Look at it carefully: What shape do you see?

The Mice (NGC 4676A and NGC 4676B) are two galaxies undergoing collision and major deformation. This is a faint target at 13th magnitude, visible in telescopes larger than 8 inches.

NGC 5128 is another bright and peculiar galaxy — the merger of a spiral and a giant elliptical. The pair has become one, but the dust of the spiral bisects the globe-shaped elliptical. Also designated as radio source Centaurus A, NGC 5128 lies about 30 million light-years away, which makes it probably the nearest major collision. The dust belt bisecting what would otherwise appear to be a circular elliptical galaxy is its most dramatic and characteristic feature.

The night sky includes many other bright colliding galaxies to observe. If you like demolition derbies, here's your chance to see the biggest smash-ups of them all — in slow motion.

Get information on how to locate 10 more interacting galaxies at www.Astronomy.com/toc.

The peculiar galaxy NGC 4618 (upper right) assumes a roughly spiral form but sports only a single arm. It interacts with nearby NGC 4625 (lower left), another one-armed galaxy. NGC 4618 dominates the view through a telescope, but its companion is actually the physically larger of the two. Dietmar Hager

The Mice are an interacting pair of spiral galaxies 290 million light-years away in the constellation Coma Berenices. The upper galaxy (NGC 4676A) is merging with the lower member of the pair (NGC 4676B) to form a new conglomeration of stars and gas. Adam Block/Mount Lemmon SkyCenter/University of Arizona

Daniel Verschatse/Antilhue Observatory

NGC 5128 may be the result of a merger. Astronomers suspect this peculiar object's bisecting dark dust lane indicates a past collision between an elliptical and a spiral galaxy.

Eclipse roundup

Totality over China

Traveling through China to witness a solar eclipse proved almost as exciting as the eclipse itself. **by David J. Eicher**

I had only a vague idea of what lay ahead of me in China, but I couldn't wait. I was as ready as possible to trek through foreign lands, hoping to witness the century's longest solar eclipse — assuming, of course, the weather cooperated.

Despite having an itinerary full of destinations and descriptions of my 2-week travels through China, I knew it would be another thing again to see and experience those places myself. Even the eclipse beckoned mysteriously, waiting to prove its exceptionality from the others I'd seen: With eclipses, you never know beforehand what the details will be like.

Prelude to adventure

Melita Thorpe of MWT Associates organized the trip, where I got to join almost 200 *Astronomy* readers and Senior Editor Richard Talcott. Some had seen solar eclipses before, although for many this would be the first time. Everyone was clearly excited. Besides the eclipse, we had the Great Wall, the famed Three Gorges Dam, and even some hanging coffins to look forward to. How could we not be excited?

David J. Eicher *is the editor of* Astronomy.

The Forbidden City was the Chinese imperial palace from 1368 to 1912. Nearly 1,000 buildings remain within the world's largest surviving palace complex. Imelda B. Joson and Edwin L. Aguirre

Flying to China took 24 hours. We passed over the Arctic Ocean and Siberia for our Chicago to Beijing flight, remaining in daylight the whole way. Moist heat above 100° Fahrenheit (40° Celsius) greeted us at the world's largest airport in Beijing. After passing through customs and grabbing our bags, I felt ready for adventure, but mostly exhausted, and I gladly passed out that night at the hotel.

Forbidden no more

Beijing is an odd place, a blend of the crumbly old and the shiny new. The city strikes you as a vast network of highways and sparkling new apartment towers, offices, and shopping complexes. It's simply stunning in scale. The city proper now boasts 18 million residents.

Under sweltering heat, we visited Tiananmen Square, the center of the city and of the political culture of the People's Republic of China. There, we saw such famous structures as the Monument to the People's Heroes, the mausoleum holding the remains of Chairman Mao Zedong, and the Ming Dynasty Gate.

Later, we explored the Forbidden City, a huge complex of palaces dating back more than 500 years but opened only decades ago. Not bad for our first day!

In Tiananmen Square, the Forbidden City's entrance features a huge portrait of Mao Zedong, the leader of the People's Republic of China from 1949 to 1976. Jim Veevaert

< Shanghai at night is a most colorful sight. The photographers took this image while aboard a boat cruising the Yangtze River. Imelda B. Joson and Edwin L. Aguirre

> The spectacular diamond ring heralds the start of totality — the most dramatic phase of a solar eclipse. Babak Tafreshi

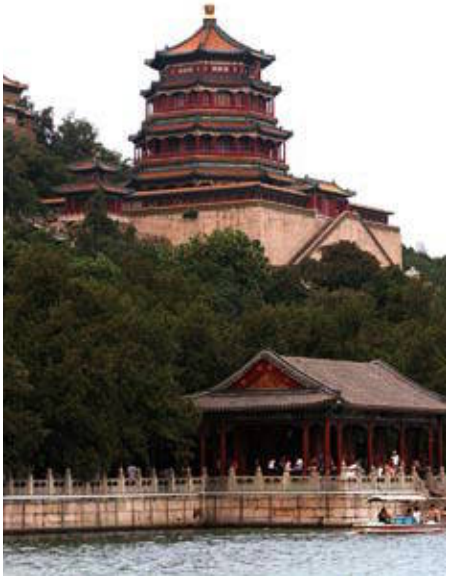
No trip to China would be complete without visiting the Great Wall, so off we went, high into the mountains northwest of Beijing, the very next day. The historic structure stunned us with its huge sections disappearing into the horizon.

Our tour guides told us men could achieve the highest grade of bravery by hiking the "really hard" section all the way to the "top," a battlement with an enclosed roof high up on the mountain. And so we did! I worried we might not be able to keep up such a pace, but things slowed down once we got to the Yangtze River later in the trip.

Touring China by boat

We boarded the *Victoria Prince*, our week-long home on the river, at Chongqing, China's most populated city. Anything marked "Made in China" probably came from that area. The river cruise gave us time to relax and gaze at the spectacular sights, both natural and man-made.

The Great Wall is China's most iconic symbol. Constructed between the fifth century B.C. and the 16th century A.D., the Great Wall stretches some 4,000 miles (6,400 kilometers). David J. Eicher

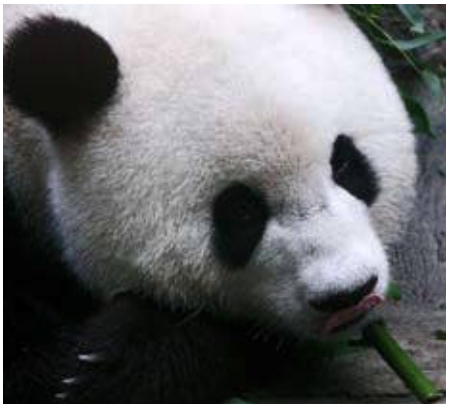


The Summer Palace is an imperial garden in Beijing. Workers finished the man-made Kunming Lake in the mid-18th century. They then used the dirt to build Longevity Hill, which the palace sits on. Imelda B. Joson and Edwin L. Aguirre

Holley Y. Bakich

The Beijing Ancient Observatory took many travelers on a trip into astronomy's history. Builders finished the observatory in 1442. Most of the instruments date back to the late 15th century.

The Three Gorges Dam spans the Yangtze River near Yichang. The hydroelectric dam is the world's largest electricity-generating plant of any kind. David J. Eicher



Imelda B. Joson and Edwin L. Aguirre

Giant pandas are bears native to central and southwestern China that have become an iconic image of the country. Several eclipse groups visited the giant panda enclosure at the Beijing Zoo.

Hanging coffins supposedly facilitated a dead loved one's passage to heaven. This site, some 2,000 years old, is in Hutang Gorge, one of China's Three Gorges. David J. Eicher

On another day, we docked near Shennong Stream and set off on a ferry excursion. After a short journey, we transferred onto tiny "peapod" boats that hold 15 passengers; a hard-working crew rowed us upstream. It was an incredible display of energy from the crew, who at one point had to get out of the boats and use ropes to pull us along the stream because of the shallow draft.

Along the way, we observed many interesting villages, caves, and, most spectacularly, hanging coffins. What in the heck are hanging coffins, you ask?

The area's ancient inhabitants thought "burying" their dead as high as possible would facilitate the journey up to heaven. Family members tied the coffins at least 2,000 years ago and stuck them in cavities of sheer rock, from dozens to hundreds of feet high.

The same day found us at the Three Gorges Dam. This $29 billion structure — the world's largest dam — generates a massive amount of hydroelectric power but won't become fully operational until 2011, after 17 years of construction.

During another day, we traveled to the Hubei Provincial Museum in Wuhan, a large city midway between Chongqing and Shanghai. Amidst the large, sprawling complex of the museum, we saw a performance of ancient Chinese music played on instruments created to match

An acrobatic show in Shanghai was one of the many artistic diversions afforded eclipse-chasers.
Jim Veevaert

Yifei Wang

Clouds obscured part or all of the eclipse of the century for some travelers and millions of Chinese. A picture like this, which shows the diamond ring through gathering clouds, isn't what eclipse-chasers hope for.

Ken Wilson

This image of the eclipsed Sun shows the red chromosphere, a thin layer of the Sun's atmosphere just above the visible surface, and Baily's beads, which are glimpses of sunlight shining through valleys on the Moon's edge.

those found in the tomb of Marquis Yi of Zeng, a feudal king buried 2,400 years ago. For a drummer like me, the percussive concert was a treat for both the ears and the eyes.

Trying to think positive

But, alluring as all this history was, we kept turning our gazes up to the heavens, both literally and metaphorically. The overcast weather, with temperatures consistently in the triple digits, never left our minds: Would the cloud cover break in time for the eclipse?

As the eclipse neared, we began exploring its scientific aspects as well, beginning with Rich Talcott's talk the night before the eclipse. The passengers had all been waiting for it, and, somehow, it got them even more excited.

We wouldn't stop at just the eclipse's science and observational aspects, though. The next day, I spoke about deep-sky objects of the Southern Hemisphere to take the conversation from the solar system out into the deeper cosmos.

It was the perfect prelude for the following day's talk by Seth Shostak, well-known SETI Institute astronomer and sometime *Astronomy* contributor, about the fate of humans on Earth. He delivered a fascinating look at how, long before the Sun kills off life on our planet, energy consumption, climate change, and population growth may spell out an end to things as we know them.

The Terra Cotta Army was a favorite of every traveler. In 1974, several farmers in Xi'an discovered this cache while drilling a well. We toured three of the four excavated pits. Together, they contain more than 8,000 figures, which date from 210 B.C. Pit 1, shown here, is the largest. David J. Eicher

Imelda B. Joson and Edwin L. Aguirre

Each Terra Cotta Warrior has a different facial expression. The army formed the guard of Qin Shi Huang, the first emperor of China. In addition to warriors, the figures include acrobats, musicians, horses, and chariots.

A wide-field view shows the vivid darkness of the sky during the eclipse's total phase and the sunset coloration around the horizon. The photographer took this image while aboard the *Costa Classica*. Travelers aboard experienced a slightly longer-than-maximum totality because the ship was sailing in the direction the shadow was moving. Babak Tafreshi

The fateful day

On Wednesday morning, though, our thoughts were on the eclipse and little else. Carefully following weather and satellite reports, we knew we might be in trouble. Rather than pushing on eastward to Wuhan, as we'd intended, we stopped the *Victoria Prince* at the city of Yichang, well to the west, and hoped for the best.

A wisp of cloud hung over the Sun when the Moon first began passing in front of it, but then the obstruction slid away, and we viewed the event in a cloudless sky. Given the poor conditions over much of the region, we felt fortunate and gave Melita Thorpe, our tour partner and the one who decided to stop short, numerous high-fives.

The temperature dropped to the low 90s during the partial phases. A long bridge behind us filled with thousands of local citizens who lined the walkway to see the amazing spectacle. Some of our group went on land into a nearby park to set up imaging equipment, but I stayed on the ship's top deck.

Rich Talcott, SETI Institute astronomer Frank Drake, and I all monitored times, and Drake called out major events to the crowd on ship. The eerie light gradually decreased following first contact while shadows sharpened. As we approached totality, we knew we were in for a real treat.

Totality!

The psychology of an eclipse crowd changes dramatically in the minutes preceding totality. People dance jigs and jump around. An occasional shout from someone excited or nervous fills the air. People snap lots of pictures. The thrill of seeing the Sun's disk grow slimmer and slimmer provides a kind of euphoria that resonates throughout the assembled masses and transforms everyone present.

Suddenly, a brilliant flash occurred as the diamond ring signaled the start of the total eclipse. The deep horizon twilight

darkened significantly; the flash of sunlight through the Moon's last valley gave way to a magnificent flower of corona, the Sun's outer atmosphere, surrounding the intensely black disk of the Moon. Screams of joy rang out across the deck! Shouts and laughter and applause! The eclipse — and our long trip — was a complete success, and this was one of the most beautiful eclipses any of us has seen.

The eclipse was unusually dark, partly because the Moon was relatively close to Earth and the Sun was relatively distant, so the lunar shadow extended wider than normal. (That also explains the eclipse's seldom-seen longevity.) We expected the corona to be elongated, but it also had many delicate streamers easily visible to the naked eye. Bright stars and planets popped out of the dark sky: Venus straight overhead, Sirius, Betelgeuse, Mars, and others. What a glorious sight!

Suddenly, after more than 5 minutes of totality, the longest eclipse any of us will ever see ended. A brilliant diamond ring flashed again, signaling the end of the best phase. As the old saying goes, totality of any duration "feels like just 7 seconds." The sheer exhilaration surging through them, the eclipse-chasers began a kind of nonstop party to celebrate what they'd seen, almost forgetting about the last half of the eclipse!

The aftermath

Like celebrating the end of something still going on, our trip was full of contrasts. Mysterious China, one of the oldest countries in the world, also proved to be supremely modern. Amidst a population of more than 1.3 billion people, I randomly bumped into American friends twice. The same day we saw the biggest dam in the world, professional rowers had to physically drag us along the water. Even celestially, we discussed matters from our local solar system to the farthest galaxies.

But the biggest and most wondrous contrast of all was the eclipse itself, as the Moon physically imposed itself between Earth and the Sun. And from this juxtaposition comes the only time we can ever see firsthand the hidden beauty of the Sun's corona. This trip revealed to us wonders we'd never imagined and beauty not soon forgotten.

It was a great observational party of amateur astronomy, and victory, like the eclipse, proved to be total.

Totality featured a red chromosphere and two prominences in this 1/60-second image. The photographer, a member of the Amateur Telescope Makers of Boston, used a Canon Rebel XTi digital SLR, a Vivitar 600mm lens at f/11, and an ISO setting of 100. Bert Halstead

During the buildup to totality, eclipse-chasers used safe, approved Mylar glasses to watch as the Moon slowly covered the Sun. Only during totality can you look at the Sun without a filter. David J. Eicher

Imelda B. Joson and Edwin L. Aguirre

The Hall of Prayer for Good Harvests is part of the Temple of Heaven complex that sits in the southeastern part of central Beijing.

To see images and videos from other trips visit www.Astronomy.com/toc.

Observing Basics

by Glenn Chaple

The Medicean stars

Jupiter's four largest moons were evidence that not all celestial bodies orbit Earth.

You're a newcomer to backyard astronomy. You've already used your telescope to explore the Moon, marveling at its majestic cratered terrain. The experience whetted your appetite to probe deeper into space. What next?

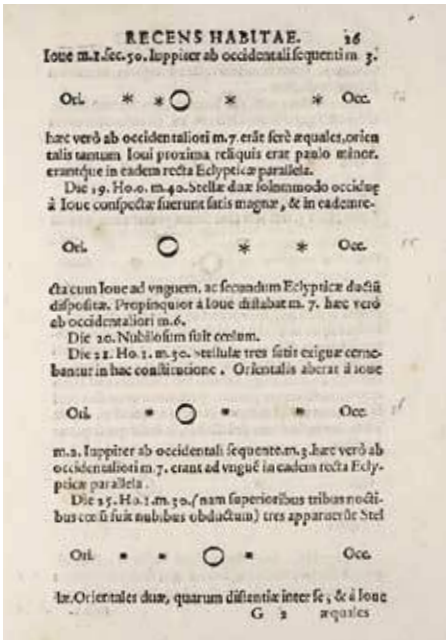
Four centuries ago, Galileo had to make the same decision. He had observed and sketched the lunar surface, its irregularities contradicting the prevalent belief that the Moon was a perfectly smooth heavenly sphere. For his next cosmic quest, Galileo chose Jupiter. What he saw changed the way we think of the universe.

When Galileo viewed Jupiter the evening of January 7, 1610, society generally believed that everything in the heavens orbited a centrally located Earth. Peering into the eyepiece, however, Galileo saw Jupiter attended by "three starlets, small indeed, but very bright." He added, "They aroused my curiosity somewhat by appearing to lie in an exact straight line parallel to the ecliptic."

Galileo initially thought they were background stars. Follow-up observations, which unearthed a fourth Jupiter companion, proved otherwise. They were satellites orbiting Jupiter. Galileo had discovered bodies that circle something besides Earth. Could Copernicus' model of a Sun-centered solar system be true after all?

Galileo announced the discovery of Jupiter's moons in his book *Sidereus Nuncius* ("Starry Messenger"). He referred to them as the Medicean stars in honor of his patron the Grand Duke Cosimo II de' Medici, a prominent member of the Medicean family of Florence.

Controversy arose when the German astronomer Simon Marius asserted that he had discovered Jupiter's moons weeks before Galileo. His claims weren't taken seriously, but the scientific community eventually accepted Marius' suggestion to name the jovian satellites Io, Europa, Ganymede, and Callisto. Marius may not have stolen Jupiter's moons from Galileo, but he stole their names from the grand duke.



RECENS HABITAE. 16

Ioue m.1.sec.50. Iuppiter ab occidentali sequentim 3.

Ori. * * ○ * * Occ.

hæc verò ab occidentalioti m.7. erãt ferè æquales, orien talis tantum Ioui proxima reliquis erat paulo minor. erantque in eadem recta Ecliptic æ parallela.

Die 19. Ho.0. m.40. Stellæ duæ solummodo occidue à Ioue conspectæ fuerunt satis magnæ, & in eadem re-

Ori. ○ * * Occ.

ctæ cum Ioue ad vnguem, ac secundum Ecliptic æ datũ dispositæ. Propinquior à Ioue distabat m. 7. hæc verò ab occidentalioti m.6.

Die 20. Nubilosum fuit cœlum.

Die 21. Ho. 1. m. 50. Stellulæ tres satis exiguæ cernebantur in hac constitutione. Orientalis aberat à Ioue

Ori. * ○ * * Occ.

m.2. Iuppiter ab occidentali sequente m.3. hæc verò ab occidentalioti m.7. erant ad vnguẽ in eadem recta Ecliptic æ parallela.

Die 25. Ho.1.m.30. (nam superioribus tribus noctibus cœlũ fuit nubibus obductum) tres apparuerũt Stel

Ori. * * ○ * Occ.

læ. Orientales duæ, quarum distantia inter se, & à Ioue

G 2 æquales

Linda Hall Library of Science, Engineering, and Technology

In drawings from *Sidereus Nuncius*, Galileo depicted Jupiter's moons as asterisks. The Italian scientist discovered Io, Europa, and Callisto January 7, 1610, and Ganymede 6 days later.

Like Galileo, we can turn to the planets once we've given the Moon its due respect. Bright and easily located, the planets are the logical next steppingstones on our cosmic voyage. Brilliant Venus regales us with its ever-changing phases. Mars, when near opposition, shows tantalizing glimpses of its surface. Who can deny the visual impact of Saturn and its fabled rings?

But Jupiter and its moons provide the most intriguing show. Apart from the remarkable sight of bright moons flanking Jupiter is their stately dance about their master. One of my earliest observing projects was a series of nightly sightings of Jupiter, sketching the positions of its moons as Galileo had. A small spotting scope with a magnification of 30x sufficed.

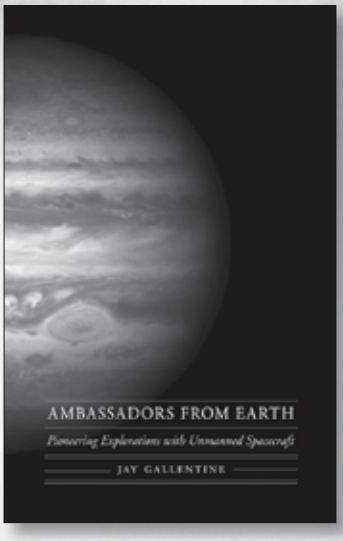
Within a week, I was familiar enough with the motions of Jupiter's moons to be able to predict with reasonable accuracy their arrangement prior to my next observation. Like Galileo, I ascertained that the nearest of Jupiter's moons circumnavigates the planet in a day or two, while the most remote requires more than 2 weeks to complete the journey.

Imagine if we could transport Galileo to the present so he could experience modern-day astronomy. He'd be honored to learn of his historical role, vindicated in knowing that science has proved the Sun-centered model of the solar system he had come to support, and relieved to know that the Roman Catholic Church, which excommunicated him for his heretical teachings, has since exonerated him. The size and complexity of today's telescopes might astonish him, as would the fact that a flotilla of space probes — including one bearing his name — has explored Jupiter and its moons close-up.

Galileo might be most amazed to discover the true nature of his little Medicean stars — each a king-sized moon with unique characteristics. NASA photos of Io's volcanic terrain, Europa's fractured icy crust, and Callisto's heavily cratered surface would leave him gasping in disbelief. Perhaps he'd derive pleasure in knowing that one of his Medicean stars, Ganymede, is the largest moon in the solar system.

Galileo's legacy lives on in each of us as we step outside on a clear night to enjoy the wonders of the night sky. As a tribute to Galileo, let's propose a figurative toast by tipping our telescopes toward Jupiter and taking a moment to admire his Medicean stars. Subscribers can follow the moons of Jupiter using Astronomy.com's StarDome Plus.

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com. Next month: the Pleiades. Clear skies!



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Evening Stars
by David H. Levy

A *Bonanza* night

The classic television program encouraged people to "look to the stars," just as many of us have at star parties and outreach events.

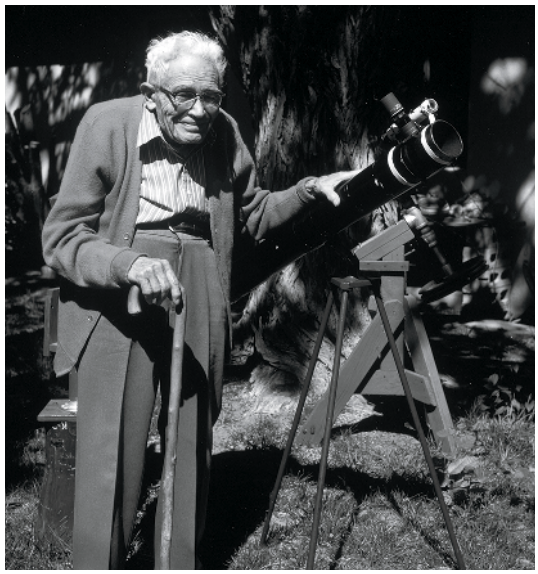
"In 1907," resonates the deep voice of Ben Cartwright in the closing scene of the March 18, 1962, *Bonanza*, "Albert Abraham Michelson, proud son of Virginia City, Nevada, became the first American to receive the Nobel Prize for his precise measurement of the speed of light."

Even though I already was totally hooked on astronomy by that Sunday evening in 1962, I'll never forget the program. My younger brother Gerry, then 11, was watching TV when it began with an image of a young boy sitting atop a roof, projecting an image of the Sun through a small brass refractor and about to set fire to Cartwright's wagon.

In this episode, the teacher Mr. Norton (played by William Schallert) has just kicked young Albert Michelson out of school. "It might be my fault," adds Adam Cartwright (played by Pernell Roberts) helpfully. "I gave Albert that astronomy book." During the episode, Albert's experiments seem to go awry every time.

Despite Albert's stumbling, the Cartwrights realize young Albert is a bright and promising boy. They participate in his speed-of-sound experiments and assist him in setting up a preliminary speed-of-light experiment. The experiment's flashing light beams spook Mr. Norton's horse. And although the teacher is unhurt, he insults Albert and his family and flatly refuses to write a letter of support for the student's application to the U.S. Naval Academy.

In astronomy, the best way to raise awareness is one person at a time.



David Levy's first telescope, Echo, has had quite a career since Levy first used it to look at Jupiter and its moons September 1, 1960. In this photograph, Pluto discoverer Clyde Tombaugh poses next to Echo. The author first saw Tombaugh a year after the *Bonanza* episode. David H. Levy

When Ben discovers later that Albert is teaching a group of several children whom Mr. Norton had also expelled — two of Hispanic descent and one of Asian descent as well as one Native American — he is enraged. Calling a town meeting, Ben charges Mr. Norton with bigotry. He introduces the expelled children, and at that point the evidence is clear.

Recognizing his crime, a disillusioned Mr. Norton looks face down and immediately begins to pack his things. Then Ben offers him a second chance. Norton offers repentance, reinstates all the children, and agrees to write a letter supporting young Albert's application to the U.S. Naval Academy.

Although the central theme of the program is bigotry, the title "Look to the stars" says it all. I believe this episode helped inspire its viewers to do just that.

Even though the tale of young Albert is mostly fictitious, it is true that he lived in Virginia City for a short while. By the time Albert reached his high school years, his family, however, had already moved to San Francisco. Moreover, President Grant did support his nomination for the Naval Academy.

Rarely is television able to affect the careers, motivations, and passions of young people. In some cases it's done a good job of inspiring people, such as in its coverage of the Apollo program and with *Cosmos* — Carl Sagan's "personal voyage" through the universe on a spaceship of his thoughts.

Movies such as *Contact* also have affected young people. What was great about *Bonanza* was that inspiration came through the story rather than from a talking head.

On March 9, 1962, only a few days prior to the *Bonanza* episode airing, I held my first astronomy outreach program. A couple hundred people joined me for an evening of movies and presentations (unfortunately it was a cloudy and rainy night in Montreal). On a high from that event, I hoped *Bonanza*, enjoyed by millions, would also nurture many young persons' aspirations.

How many people watched the program and then went outdoors and really looked at the stars? Maybe one or two, ten or a hundred. It doesn't matter. In astronomy, the best way to raise awareness is one person at a time, whether that inspiration comes from a lecture, a TV show, or a movie.

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by Michael E. Bakich

Steve Cullen

President, LightBuckets

Steve Cullen started LightBuckets in his head in October 2007. Brad Ehrhorn of RC Optical Systems was delivering a 24-inch Ritchey-Chrétien that was going to be Cullen's personal telescope. When it came out of the trailer, he thought, "Wouldn't it be cool if everyone could have a telescope like this?" He decided to make that a reality, at least virtually. LightBuckets was up and running by May 2008.

Born in Niagara Falls, New York, Cullen grew up in Ohio. He has lived in several southwestern cities. He now operates LightBuckets in Rodeo, New Mexico.

Cullen began working in the software world in 1985. For the 9 years prior to founding LightBuckets, he was a senior vice president at Symantec, where he ran its enterprise and consumer security business unit.

Steve Cullen started LightBuckets in 2008. Here, he holds a large monitor showing his web site's home page. Image courtesy LightBuckets

What's your most popular product?

Our most popular telescope in the LightBuckets Telescope Network is the 24-inch Ritchey-Chrétien in New Mexico. This size instrument is something you'd typically find at a university or in a research environment. But with LightBuckets, people can access its capabilities online no matter where they live in the world.

Tell me something cool about LightBuckets.

Being a technology geek and a businessman, superhuman feats in either of those areas impress me. One of the coolest "behind the scenes" things is that one person, my engineering vice president, Alvin Jeng, wrote the entire web interface.

What is even more astounding is that he developed the entire LightBuckets web site and all of our automation systems without ever having seen or used a telescope, planetarium application, or astronomical image processing software. That's one smart dude!

Describe your latest equipment and software.

We've added a 12.5-inch Ritchey-Chrétien in New Mexico and a 16-inch Ritchey-Chrétien in Australia. But the biggest change has been our web interface. Two unique features are SkyView and RunTrack.

SkyView is our visual targeting, framing, and guide-star selection component. It allows customers to choose their target, change the instrument rotation, and automatically select the right star for guiding.

RunTrack displays real-time observatory telemetry during imaging. Customers can view the weather, the all-sky camera, the cloud sensor, and all instrumentation activity. It also lets customers replay the events to check guiding, wind speed, and seeing conditions.

Steve Cullen

Do you enjoy observing?

I enjoy it very much, although running a business and spending time with my wife, Cindy, leaves little time for it. Visually, I enjoy the planets, the Moon, and the Sun. I suppose that's because our imaging platforms are so well-suited to deep-sky and wide-field targets that I don't get to see the closer-in stuff firsthand that often.

What does the future hold?

We're working on a complete redesign of our web site. One area that we're focusing on is our scheduling options. Customers currently have three choices for scheduling: "Now" (immediate access); "Best Available" (our automated scheduler picks the best time to image the target); and "Later" (customers select dates for their imaging). We're working to make "Best Available" more useful so customers can set specific criteria that must be met before their imaging run begins.

Where, in your opinion, is the hobby headed?

I believe the hobby is headed toward online astronomy. To be clear, nothing can replace the experience of taking a telescope out under the stars. But many people live in light-polluted locations or have poor weather. And it's not easy to head to Australia to view the southern sky when the urge strikes! That's where LightBuckets comes in. I believe we're at the forefront of a revolution in astronomy where everyone can participate no matter their age, experience level, or location.

"I believe the hobby is headed toward online astronomy."

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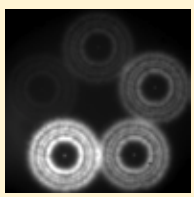

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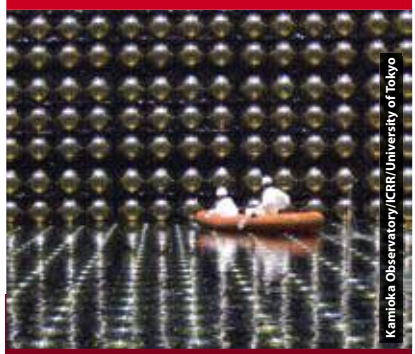

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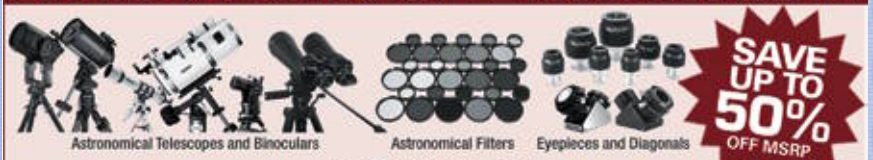

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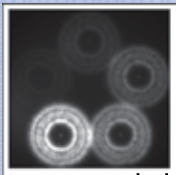
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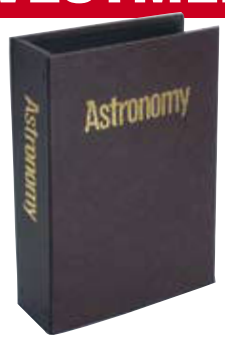

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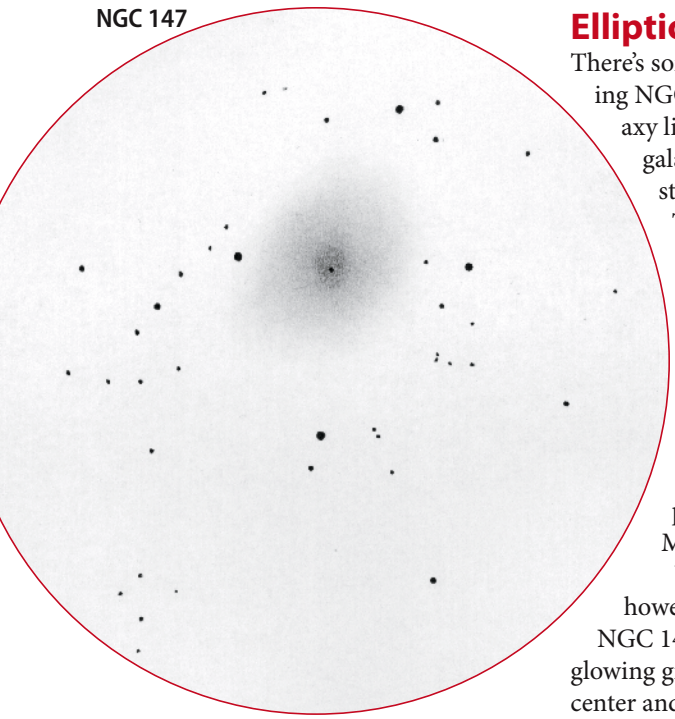
Galaxies NGC 147 and NGC 253

Astronomy's editor sketches two of his favorite objects.
by David J. Eicher

NGC 147



NGC 147 sketched by David J. Eicher using a 17.5-inch f/4.5 reflector at 71x.

Elliptical galaxy NGC 147

There's something special about observing NGC 147. This dwarf elliptical galaxy lies in a strange place for a little galaxy, high in a Milky Way sky studded with stars in Cassiopeia. The neat thing about it is that NGC 147 is a satellite, an outlying cousin, of the Andromeda Galaxy (M31). Another faint M31 satellite, NGC 185, lies nearby. Both are challenging objects for small telescopes because they are faint objects whose light needs to punch through the band of Milky Way glow.

With a medium-sized scope, however, these galaxies come alive. NGC 147 appears as a cottony fuzz glowing gray-green with a condensed center and a field star that appears right on top of the galaxy's nucleus. Through my 17.5-inch scope at 71x, I see the galaxy in a rich field of bright and faint stars liberally sprinkled everywhere.

Knowing the galaxy is a little runt and that it's close, a member of our Local Group, makes it a fascinating object to gaze at. Just spotting it carries its own special, almost magical, rewards.

NGC 147

Bernhard Hubl

Position: 0h33m, 48°30' (2000.0)
Type: dE5
Constellation: Cassiopeia
Magnitude: 9.3
Size: 12.9' by 8.1'
Distance: 2.3 million light-years

NGC 253

Bernhard Hubl

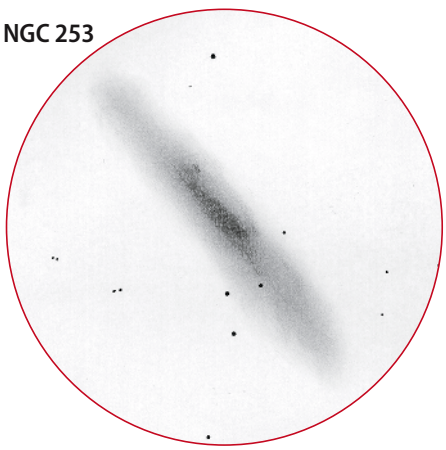
Position: 0h48m, –25°17' (2000.0)
Type: Scp
Constellation: Sculptor
Magnitude: 7.1
Size: 25.1' by 7.4'
Distance: 10.9 million light-years

Spiral galaxy NGC 253

A bigger, much brighter galaxy than NGC 147, NGC 253 lies in Sculptor and so requires a clear southern horizon and a dark night for most observers to see it. Sometimes called the Silver Coin Galaxy, this object was for years thought to be an ordinary, ho-hum nearby spiral. NGC 253 is a starburst galaxy, however, undergoing a violent and energetic surge of star formation. Through a moderate or large backyard scope, you can detect signs of this intense star formation by an irregularly shaped distribution of brightness along the galaxy's center.

On a dark night, aim your scope at NGC 253, and use low powers for the best overall view. You'll see a highly inclined glowing disk with a bright center and several bright field stars, including a triangle near the galaxy's southwestern edge. Increasing the magnification may show you some irregularity in brightness along the galaxy's hub. You will notice a smooth halo along the disk.

NGC 253



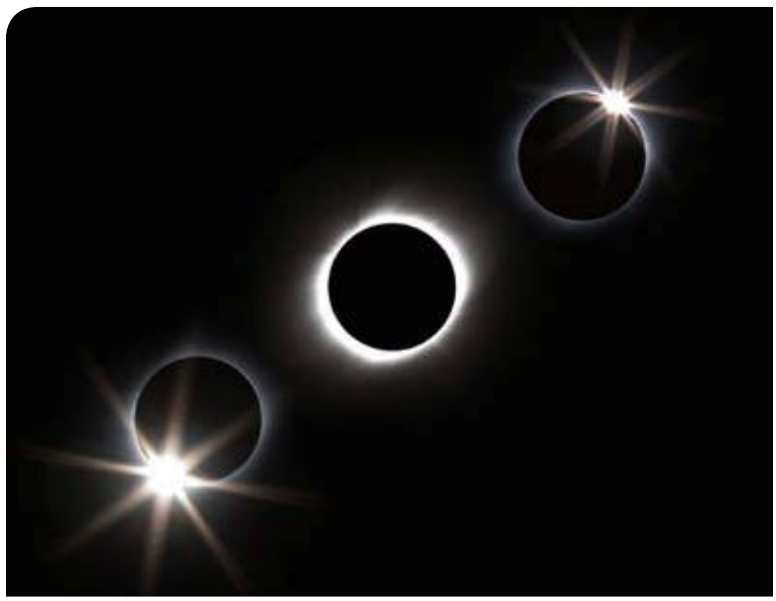
NGC 253 sketched by David J. Eicher using an 8-inch f/10 SCT at 50x.

David J. Eicher *is the editor of* Astronomy. *He has observed and sketched deep-sky objects for 33 years.*

These images show the Sun's inner and outer corona. (Canon Rebel XT digital SLR, 500mm lens at f/8, ISO 400, 1/2000-second (inner) and 1/8-second exposures, taken on the *Costa Classica* just north of Iwo Jima) • Ken Wilson, Mechanicsville, Virginia

Earth, Moon, and Sun align

None of nature's wonders thrills viewers as much as a total solar eclipse. As the Moon slowly covers the Sun, shadows sharpen, birds come in to roost, and normally nighttime celestial objects pop into view. The most recent eclipse occurred July 22, 2009, and by all accounts it was one of the darkest in memory. Although clouds covered much of the shadow's path across our planet, intrepid astro-imagers on land and aboard ship managed to get enough clear sky to photograph the spectacle. After the event, eclipse-chasers began discussing the next total solar eclipse, which will occur July 11, 2010.



Two diamond rings frame the midpoint of July's total solar eclipse in this composite image. (Canon 20D digital SLR, 400mm lens, ISO 1600; bottom left to upper right: 1/40-second at f/36, 1/60-second at f/7.1, and 1/80-second at f/36, taken July 22, 2009, aboard the *Costa Classica* just north of Iwo Jima) • Babak A. Tafreshi, Tehran, Iran

Spiral galaxy M88 in Coma Berenices shines at magnitude 9.6, making it one of the sky's brightest galaxies. As you move your telescope toward M88's position, you'll see the glow of dozens — if not hundreds — of fainter galaxies. (24-inch RC Optical Systems Ritchey-Chrétien telescope at f/8, SBIG STL-11000 CCD camera, LRGB image with exposures of 150, 50, 50, and 50 minutes, respectively) • Adam Block/Mount Lemmon SkyCenter/University of Arizona

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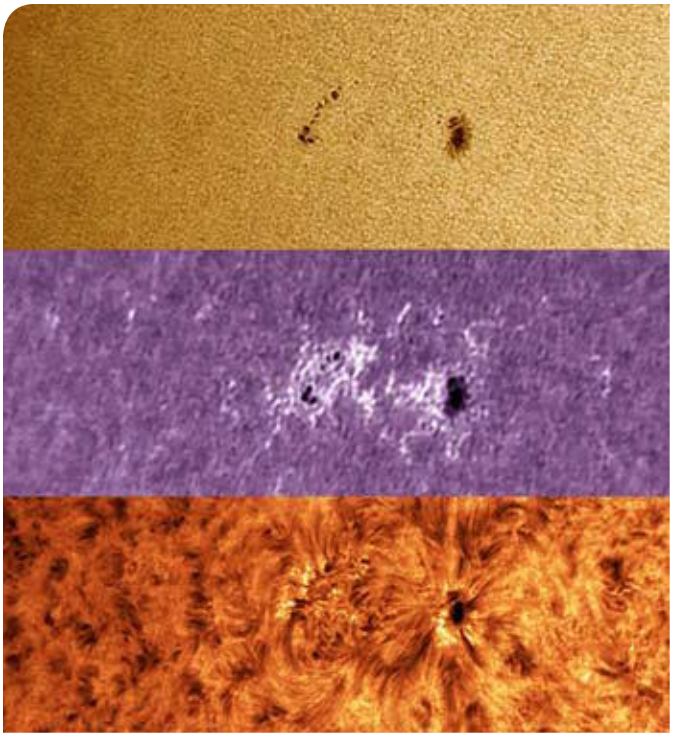

Sunspot group AR11005 appears different through a visual filter (top), a Calcium-K filter (middle), and a Hydrogen-alpha filter (bottom). (White-light and Hydrogen-alpha images: 4-inch Vixen FL102S refractor at f/22.5 and f/27, respectively; Calcium-K image: Coronado CaK solar telescope at f/50; all images taken through a Lumenera SKYnyx2-0M CCD camera, October 12, 2008) • Pete Lawrence, Selsey, England

Spiral galaxy M61 in Virgo appears face-on to us, but its arms wind tightly around its core. The image contains two other spiral galaxies: Magnitude 13.4 NGC 4292 lies to M61's upper left, and magnitude 12.9 NGC 4301 hovers at its lower left. (9.25-inch Celestron 925 Schmidt-Cassegrain telescope at f/6.3, SBIG ST-4000XCM CCD camera, twenty-seven 10-minute exposures, stacked) • Hunter Wilson, Lexington, Ohio

The Seagull Nebula (IC 2177) in the constellation Monoceros is an emission nebula that spans 2°. The small, detached, bright part left of center is the Seagull's head, which carries the separate designation NGC 2327. You'll find the Seagull Nebula 7.8° northeast of Sirius (Alpha [α] Canis Majoris). (4-inch Takahashi apochromatic refractor, SBIG ST-11000 CCD camera, LRGBHα image with 110 minutes total exposure) • John Chumack, Dayton, Ohio

reader gallery

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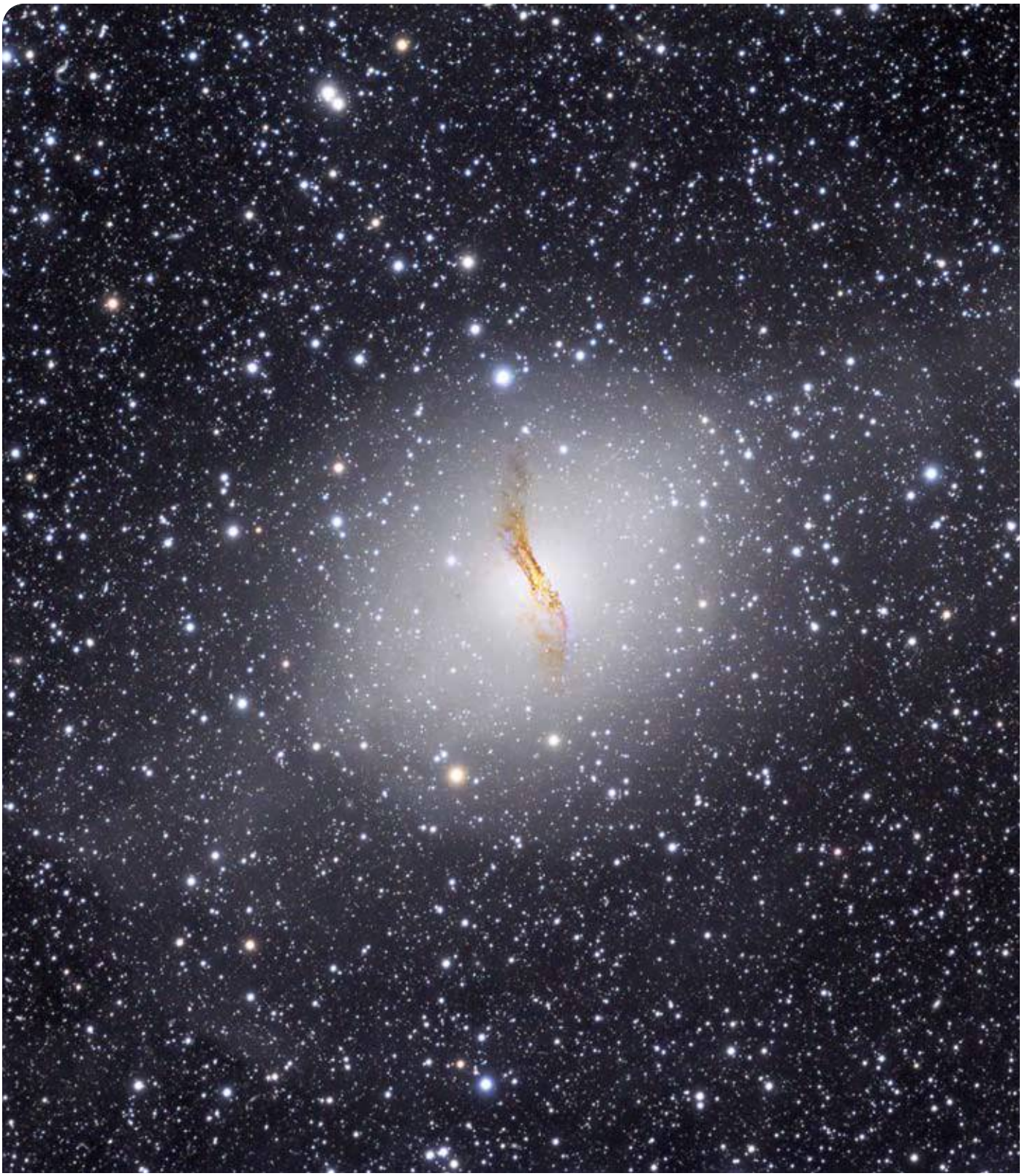

Centaurus A (NGC 5128) is a peculiar galaxy 14 million light-years away in Centaurus. This image, made up of 19.5 hours of exposures, reveals the galaxy's intensely bright core, intricate dust lane, and enormous halo, which extends 70,000 light-years from the core. Faint polar extensions, perpendicular to the dust lane, extend more than twice that distance. (6-inch Astro-Physics StarFire 152 EDF refractor at f/7.5, FLI Proline 11002 CCD camera, LRGB image with exposures of 900, 90, 90, and 90 minutes, respectively) • Michael Sidonio, Googong, New South Wales, Australia

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Mount	Model	Price	Rebate
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Every LX200 comes standard with:

1 **Advanced Coma-Free™ Optics.** ACF design produces a coma-free, flatter field of view with no diffraction spikes that equals traditional Ritchey Chrétien systems at a fraction of the cost. Combine this with Meade's patented UHTC™ coatings that increase light transmission by 20% over standard coatings, for the sharpest, brightest images you can get.

2 **Primary Mirror Lock.** Eliminates focus and mirror shift during long exposures. Like all of the features on this list, a Meade exclusive.

3 **Smart Mount™ And Smart Drive™.** The LX200 constantly refines pointing accuracy each time an object is centered and provides Permanent Periodic Error Correction on both axes over the course of one or more training periods. Works in both alt-az and equatorial modes.

4 **Solid Fork Mount With Heavy Duty 5.75" Gears.** Large, high-quality worm-gear drives in both axes provide smooth movements with low periodic error that are critical for long exposure astrophotography. Providing the freedom to go horizon to horizon without any meridian flip, unlike German Equatorial Mounts.

5 **Autostar II Controller**. Puts over 145,000 objects at your fingertips with the fastest GoTo performance available (8° per second). Or you can control the system from an external computer.

6 **Rock-Solid Field Tripod.** Depending on aperture, each LX200 comes with an adjustable Standard Field Tripod, Giant Field Tripod or Super Giant Field Tripod for a solid, research-grade foundation.

To customize your LX200, these optional accessories are also available:

7 **NEW! Series 5000 Auxiliary Equipment Mounting System.** Machined aluminum dovetail plates, rings and counterweight systems (shown here with the Series 5000 102mm ED APO refractor) designed specifically for the Meade LX series of telescopes. They join seamlessly to create the ideal custom configuration. Available for 8", 10", 12", 14" and 16" LX scopes.

8 **Zero Image-Shift Microfocuser.** Allows precise focus with no image movement at four speeds with a press of a button. Perfect for long exposure astrophotography.

9 **Heavy-Duty Ultra Wedge**. For precise polar alignment in equatorial mode which eliminates field rotation in long-exposure astrophotographs. Die-cast aluminum construction and no-tool knobs for quick and sturdy set up.

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Because the LX200-ACF is reliable, light weight, compact and easy to use, it is *the* telescope of choice for thousands of amateur astronomers around the world.

For more information about the LX200-ACF line of telescopes go to meade.com.

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